ROYAL OBSERVATORY, HONG KONG

TECHNICAL NOTE NO. 69

HYDROMETEOROLOGICAL ASPECTS OF THE HEAVY RAIN ON 17 JUNE 1983

BY

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1. INTRODUCTION

On 17 June 1983, a total of 346.7 mm of rain was recorded at the Royal Observatory. This daily rainfall figure ranks the fourth highest in the historical records of the Royal Observatory, which began in 1884. A time sequence of the hourly rainfall is shown in Fig. 1. As the rainfall on the preceding day (16 June) and the succeeding day (18 June) were only 1.6 and 3.8 mm respectively, emphasis in this study has been placed on 17 June alone.

This report presents analyses of the rain occurring on that day. Data from stations in China were used in the analysis of areal distribution of rainfall over south China. Rainfall data obtained from various stations in Hong Kong were used in the derivation of rainfall intensity, spatial and temporal distributions, storm frequency estimation, mass curves and depth-area-duration relationship.

Unless otherwise specified, all times used in this report refer to Hong Kong Time, which is 8 hours ahead of the Greenwich Mean Time (GMT). Also, unless otherwise stated, rainfall figures refer to those recorded at the Royal Observatory Headquarters.

A brief description of flooding, landslips and losses and damage caused by the heavy rain is given in Appendix 1.

2. COMPARISON OF RAINFALL RECORDS AT THE ROYAL OBSERVATORY

For durations ranging from 15 seconds to 1 day, none of the rainfall records at the Royal Observatory were broken. The daily total (midnight to midnight value) of 346.7 mm ranks the fourth highest since 1884 and the second highest for the month of June. The maximum 5-hourly rainfall of 274.4 mm between 5 and 10 a.m. that day ranks the fourth in the historical records. In terms of frequency of recurrence of the heavy rain, Gumbel's statistics of extreme values presented by Peterson and Kwong (1981) suggest a return period of about 17 years for the daily total and about 38 years for the 5-hourly value. Table 1 gives the rainfall amounts, their ranking and the estimated return periods of the maximum rainfall values recorded over various durations of time.

The total rainfall that day constituted about 78 % of the month's total of 445.8 mm. The average rainfall of the month is 431.8 mm (1951-1980).

3. RAINFALL OVER SOUTH CHINA

Rainfall distribution over south China during the 48-hour period ending at 8 a.m. (00 GMT) on 18 June (Fig. 2) shows that Hong Kong received the largest amount of rainfall along the coastal area.

An infrared satellite picture taken at 2 a.m. on 17 June (Plate 1) shows convective cloud already covering Hong Kong and extending about 100 km across. The brightest patch in the cloud area indicates cumulonimbus clouds with tops extending to 14 000 m in altitude. However, it was not until around 4 a.m. that intense rainfall was measured locally over the New Territories. The cloud area remained almost stationary up to 5 a.m. (Plate 2). It shifted to the south by 8 a.m., but still covered Hong Kong (Plate 3). Convective clouds stayed over the area (Plates 4-7) until around midnight, when on the satellite picture (Plate 8) Hong Kong was located in a relatively clear area surrounded by three systems of convective clouds.

The sequence of satellite pictures also show another area of convective clouds, originally over west China (Plate 1), moving eastward towards the quasi-stationary cloud area near Hong Kong. The speed of movement of this cloud area, about 15 knots, explained the relatively smaller rainfall reported by stations to the west of Macau.

4. SHORT-DURATION RAINFALL INTENSITY DURING THE HEAVY RAIN

The methods of rainfall measurement in Hong Kong are described in Appendix 2 of Lee (1983). In June 1983, there were 92 ordinary rain-gauges, 26 autographic tilting-siphon gauges, 3 autographic tipping-bucket gauges, 38 telemetering tipping-bucket gauges and 4 Jardi rate-of-rainfall recorders. Rainfall data from the telemetering gauges are available at 5-minute intervals.

The Jardi 'instantaneous' rate-of-rainfall recorders are located at the Royal Observatory, King's Park, Airport Meteorological Office and Tate's Cairn. The maximum instantaneous rates recorded during the rainstorms are listed in Table 2. The maximum instantaneous rate of 283 mm/h occurred at around 0635 H at Tate's Cairn. For the purpose of comparison the reader can refer to Table 3 of Lee (1983), in which intensities exceeding 200 mm/h over the period 1981-1982 were listed. The maximum instantaneous rates recorded on 17 June are not infrequent.

Intensities over a duration of 15 minutes or more are estimated from records of autographic gauges. As a supplementary source of data, 5-minute totals from three telemetering gauges were also used to obtain 15-, 30-, 60- and 120-minute rainfall maxima (Table 3). It should be noted, however, that because of the discretization in time, maximum rainfall estimated from such 5-minute reports (to within 0.5 mm, which was the bucket size) could miss peaks in rainfall intensity.

The values in Table 3 indicate that the most intense rainfall occurred over Kowloon, Hong Kong Island and the southern part of Lantau Island. The minimum was located over the northwestern part of the New Territories.

The maximum rainfall in 120 minutes, irrespective of the time of occurrence, is plotted (Fig. 3) using supplementary data derived from the network of telemetering tipping-bucket rain-gauges. In view of the presence of a rainfall maximum observed over the Sha Tau Kok area in the 24-hour period from 3 p.m. on 17 June to 3 p.m. on 18 June, (Fig. 7) there might be another maximum over the area. This is marked as an area bounded by a dashed line in Fig. 3. However, this cannot be positively confirmed as there was no continuous recording gauge in the area.

With regard to the spatial variation of short-duration rainfall amounts (Table 3), there are a few points worth mentioning. Over durations of 30, 60 and 120 minutes, the maximum rainfall amounts were recorded at Stanley in the afternoon of 17 June and were 84 %, 120 % and 45 % respectively higher than the corresponding values recorded at the Royal Observatory in the morning. The maximum 15-minute rainfall also occurred at Stanley at around 1600 H and exceeded 60 mm, which was about 90 % higher than the corresponding value at the Royal Observatory. Over durations of 15, 30, 60 and 120 minutes, the smallest of the maximum rainfall among various stations, which occurred over the northern part of the New Territories, were less than 50 % of the corresponding values at the Royal Observatory.

Locations of local places mentioned in this section and in the following sections are shown in Figs. 4 and 5.

5. DAILY RAINFALL OVER HONG KONG

Daily rainfall amounts mentioned in this section are 24-hour values ending at 3 p.m. on each day.

The distribution of the daily rainfall ending at 3 p.m., 17 June, is presented in Fig. 6. Over 200 mm of rain were recorded in the southern part of Sha Tin, Sai Kung, Kowloon, Lantau Island, Hong Kong Island and the outlying islands in the south. Stations in the southern part of Lantau and in Wan Chai and Eastern District of Hong Kong reported more than 400 mm of rain.

The rainfall distribution during the following 24-hour period is presented in Fig. 7. Over 100 mm of rain fell on the southern part of Hong Kong Island, Waglan Island and the northern part of the New Territories, near Sha Tau Kok.

The evolution of the hourly rainfall from midnight, 16 June to 2100 H, 17 June, are shown in Fig. 8(i) through Fig. 8(xxi). There was little rain between midnight and 3 a.m. (Figs. 8(i)-(iii)). Between 3 a.m. and 4 a.m., about 10 mm of rain fell in Yuen Long and in the southern part of Sha Tin (Fig. 8(iv)).

By 5 a.m., a southwest-northeast oriented rainband developed and maximum rainfall was concentrated over Tai Mo Shan, where 47 mm of rain fell in an hour (Fig. 8(v)).

Between 5 and 6 a.m., the area of maximum rainfall was centred over Sham Shui Po and the southern part of Sha Tin, where over 80 mm of rain were recorded (Fig. 8(vi)). In the following hour, this rainband shifted in a generally southerly direction to affect Kowloon, Hong Kong Island and the southern part of Lantau (Fig. 8(vii)). Rain started to abate in the New Territories.

Hong Kong Island received the most intense rainfall between 7 and 8 a.m. (Fig. 8(viii)). The area of maximum rainfall continued to move southward. Between 5 and 10 a.m., over 200 mm of rain fell in Kowloon, Junk Bay, High Island East and Hong Kong Island (Figs. 8(vi)-(x)).

The intensity of rainfall decreased after 10 a.m. Between 10 and 11 a.m., areas receiving more than 10 mm of rain were confined to Cheung Chau Island and the southeastern part of the territory (Fig. 8(xi)). The rain decreased further in the following hour (Fig. 8(xii)).

Between noon and 1 p.m., an area of rain appeared over the southern part of Lantau (Fig. 8(xiii)). This then spread to Hong Kong Island and Clear Water Bay (Figs. 8(xiv)-(xvi)). By 4 p.m., rain abated over most parts of the territory, but intense, localized thunderstorms still affected the southern part of Hong Kong Island, Waglan Island and, by inference from the 24-hour rainfall at Sha Tau Kok (Fig. 7), the northern part of the New Territories (Fig. 8(xvii)). Of particular interest is that more than 180 mm of rain were recorded at Stanley in an hour. This amount exceeds by a wide margin the highest hourly rainfall, 108.2 mm, ever recorded at the Royal Observatory (12 June, 1966). The 24-hour rainfall at the station recording this event was found to be consistent with that recorded at a nearby station equipped with an ordinary rain-gauge (Fig. 7).

The rainfall pattern remained similar in the following hour (Fig. 8(xviii)).

Between 6 p.m. and 7 p.m., rain was concentrated over Tai Mo Shan, Tsuen Wan, Sha Tin and the northern part of Sai Kung, where more than 20 mm of rain fell (Fig. 8(xix)). Rain started to decrease after 8 p.m. (Figs. 8(xx)-(xxi)).

Mass curves, i.e. plots of accumulated rainfall versus time of day, for the Royal Observatory, Yuen Long, High Island West, Victoria Peak, Shek Pik Reservoir and Stanley are presented in Fig. 9.

6. DEPTH-AREA-DURATION ANALYSIS

Depth-area-duration analysis was carried out to determine if there is any significant variation, both in time and space of the rainfall pattern, at different locations of Hong Kong. The procedure of the analysis follows recommendations in the Guide to Hydrological Practice published by the World Meteorological Organization (1974) and a brief description can be found in Lee (1983).

The resulting graph showing area versus depth curves for each duration of time, i.e. 60 minutes, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours and 9 hours, is given in Fig. 9. Apart from the 60-minute values, rainfall values for the other durations are obtained from accumulation of hourly rainfall figures. The enveloping depth-area-duration values for each increment of area and duration are tabulated in Table 4.

For the 17 June rainstorms, closed isohyets around storm centres generally cover areas of about 100 sq. km. The results presented in Fig. 9 show that, with the storm area in the range of 10 to 100 sq. km, the maximum average rainfall varied by less than 30 mm. Also, the temporal variation is found to be fairly uniform for duration between 60 minutes to 5 hours -- roughly about 50 mm for each increment of one hour. For a duration of 60 minutes, the maximum average rainfall is close to 100 mm over the range of areas studied.

The intense storms on 17 June, which occurred over relatively short periods, resulted in slightly larger 6-hourly maximum average rainfall than the rainstorms in May 1982 (Lee, 1983).

7. CONCLUSIONS

During the rainstorms on 17 June, both the amount of 346.7 mm over the day and the maximum 5-hourly rainfall of 274.4 mm between 5 and 10 a.m. rank the fourth highest in the historical records of the Royal Observatory since 1884. These values were estimated to correspond to return periods of about 17 and 38 years respectively.

Short-duration rainfall intensities recorded at the Royal Observatory were found to be not infrequent (Table 1). The extent to which short-duration rainfall varies over Hong Kong is illustrated by the fact that, among various stations, the smallest maximum depths recorded for durations from 15 to 120 minutes were about 50 % less than those recorded at the Royal Observatory, and that the largest of these maximum rainfall values, recorded at Stanley, were 45 to 120 % higher than the corresponding values recorded at the Royal Observatory that day.

The heavy rain in the morning was associated with a rainband moving southward from the New Territories to Hong Kong Island and the outlying islands in the south. The rain in the afternoon was associated with scattered but concentrated thunderstorms which affected the southern part of Hong Kong as well as the Sha Tau Kok area in the north.

Results of a depth-area-duration analysis show that, in the rainstorms, for areas in the range of 10 to 100 sq. km the variation of the maximum areal rainfall depths was small. On the other hand, the rainfall intensity was fairly uniform over durations in the range of 60 minutes to 5 hours.

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1.	Chen, T.Y.	1969	The Severe Rainstorms in Hong Kong during June 1966, Royal Observatory Supplement to Meteorological Results 1966.
2.	Cheng, T.T. and M.C. Yerg, Jr.	1979	The Severe Rainfall Occasion, 16-18 June 1972, Royal Observatory Technical Note No. 51.
3.	Lee, B.Y.	1983	Hydrometeorological Aspects of the Rainstorms in May 1982, Royal Observatory Technical Note No. 68.
4.	Peterson, P. and H. Kwong	1981	A Design Rain Storm Profile for Hong Kong, Royal Observatory Technical Note No. 58.
5.	World Meteorological Organization	1974	Guide to Hydrological Practices, WMO Report No. 168.

APPENDIX 1

DAMAGE AND LOSSES CAUSED BY THE RAINSTORMS ON 17 JUNE 1983

The following damage and loss statistics were based on those reported in the June 1983 issue of the Monthly Weather Summary published by the Royal Observatory. Press reports were also collated as appropriate.

During the rainstorms, there were a total of 393 reports of flooding and 134 reports of landslips. The majority, 261 reports of flooding and 92 reports of landslips, occurred on Hong Kong Island.

The rainstorms resulted in a man killed, 12 people injured and more than 600 made homeless. The most serious flooding occurred in the eastern and southern districts of Hong Kong Island, the eastern part of Kowloon, Fan Ling and Kam Tin, where flood water of 1 metre deep was reported. A total of about 36 hectares of farmland in the New Territories, Lantau Island and Lamma Island were inundated.

The most serious landslip occurred in the morning at Peak Road, Victoria Peak, where a section of the road slid down the slope. The landslip cut off electricity and water supply as well as telephone links to the Peak. In the evening another serious landslip occurred at Aberdeen where about 50 tonnes of mud slid down the hillside, burying 6 motor vehicles but no one was hurt.

On Hong Kong Island, eight buildings were threatened by landslips and were closed by the authorities.

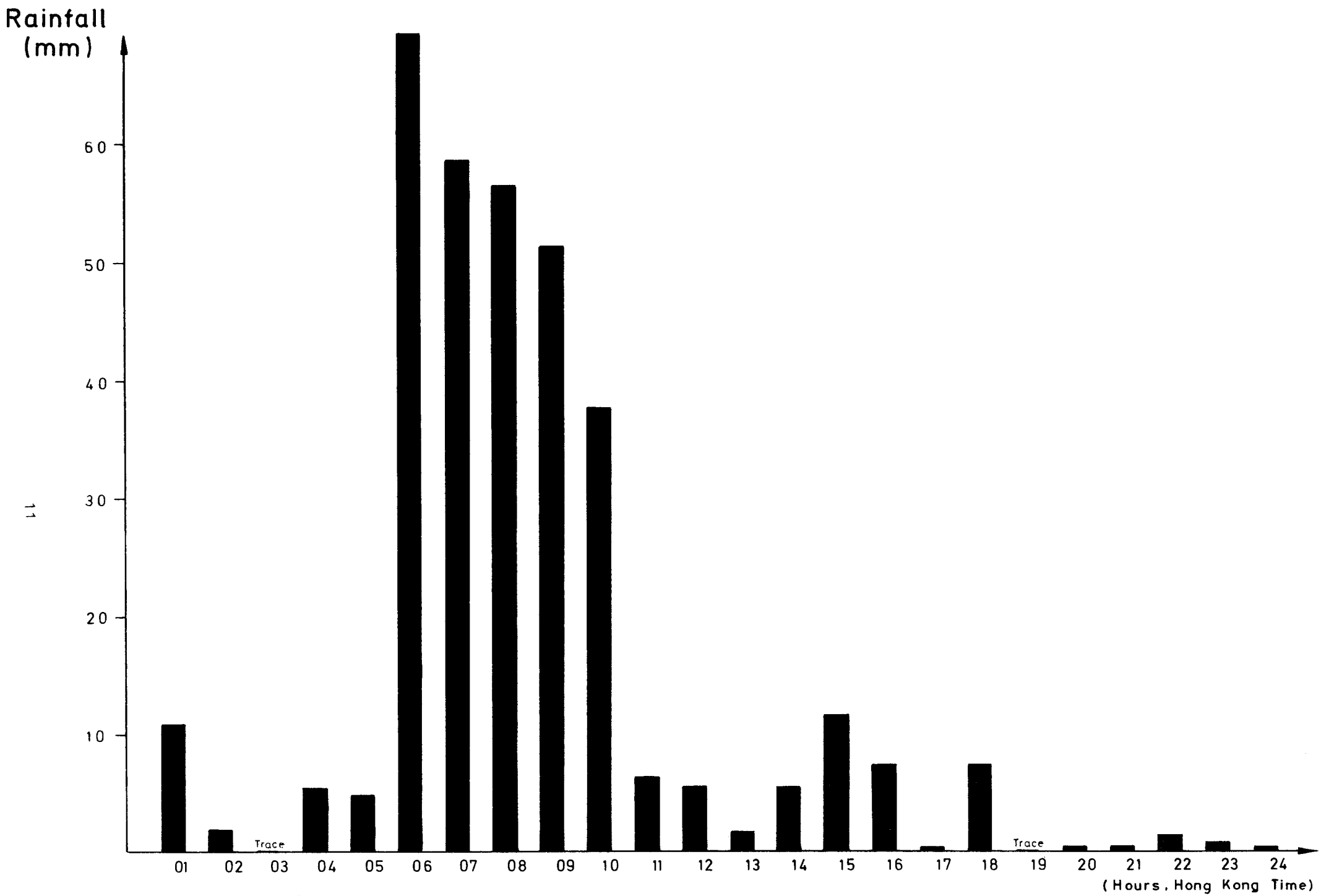


Fig.1 Time sequence of hourly rainfall on 17 June 1983, Royal Observatory

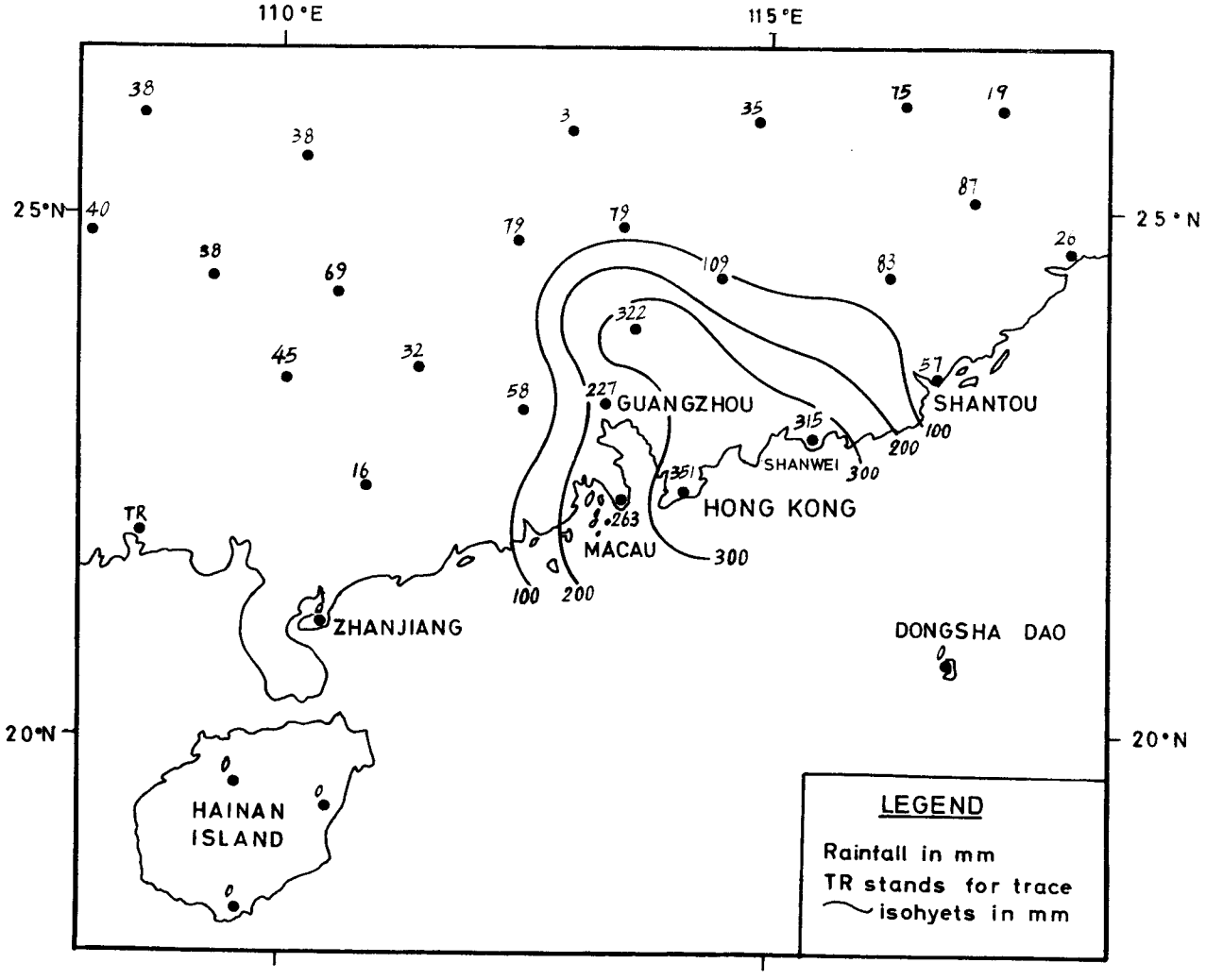
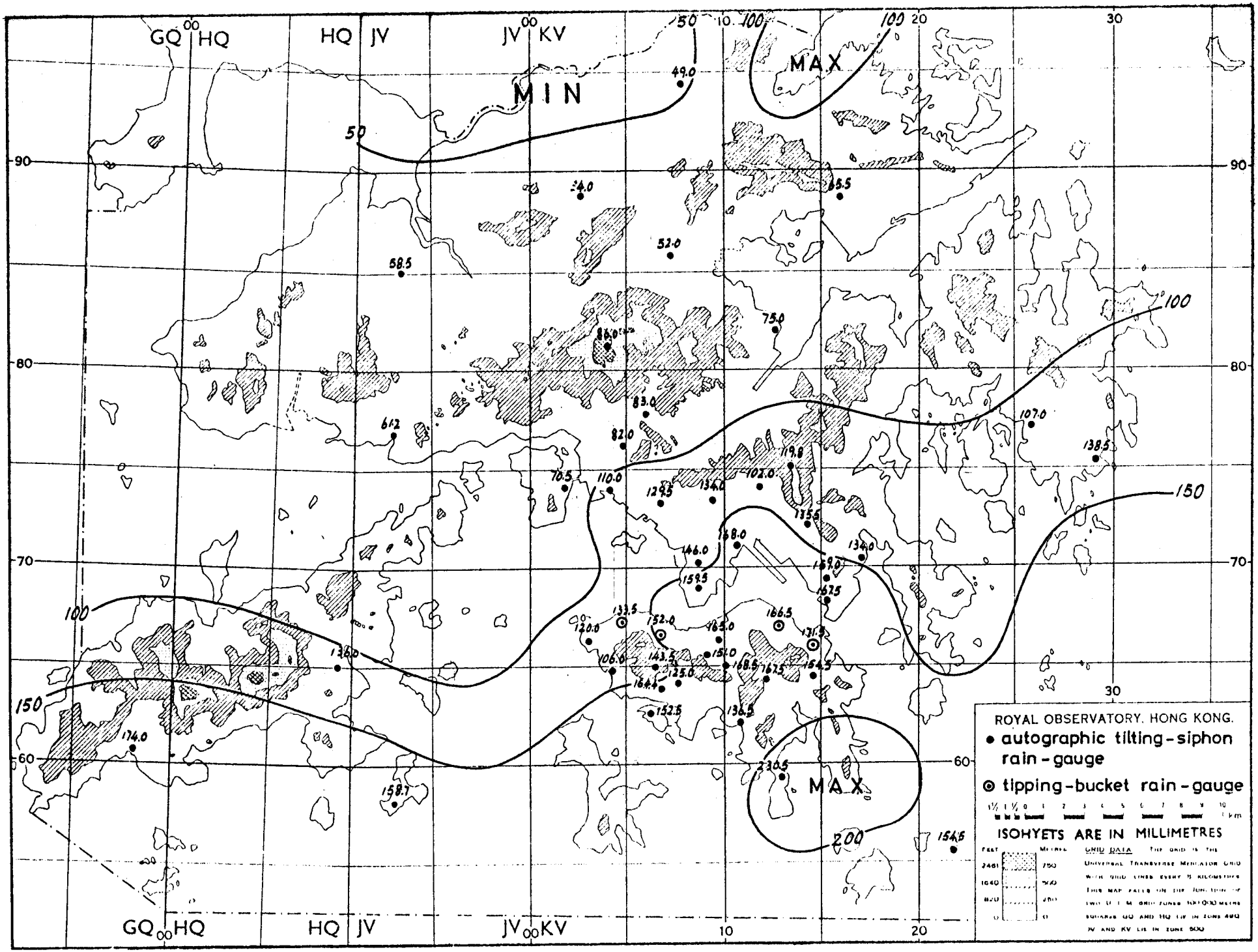


Fig. 2 Rainfall distribution over south China-
8 a.m. 16 June 1983 to 8 a.m. 18 June 1983



R.O. 128 Fig. 3 Maximum 120-minute rainfall, irrespective of the time of occurrence on 17 June 1983

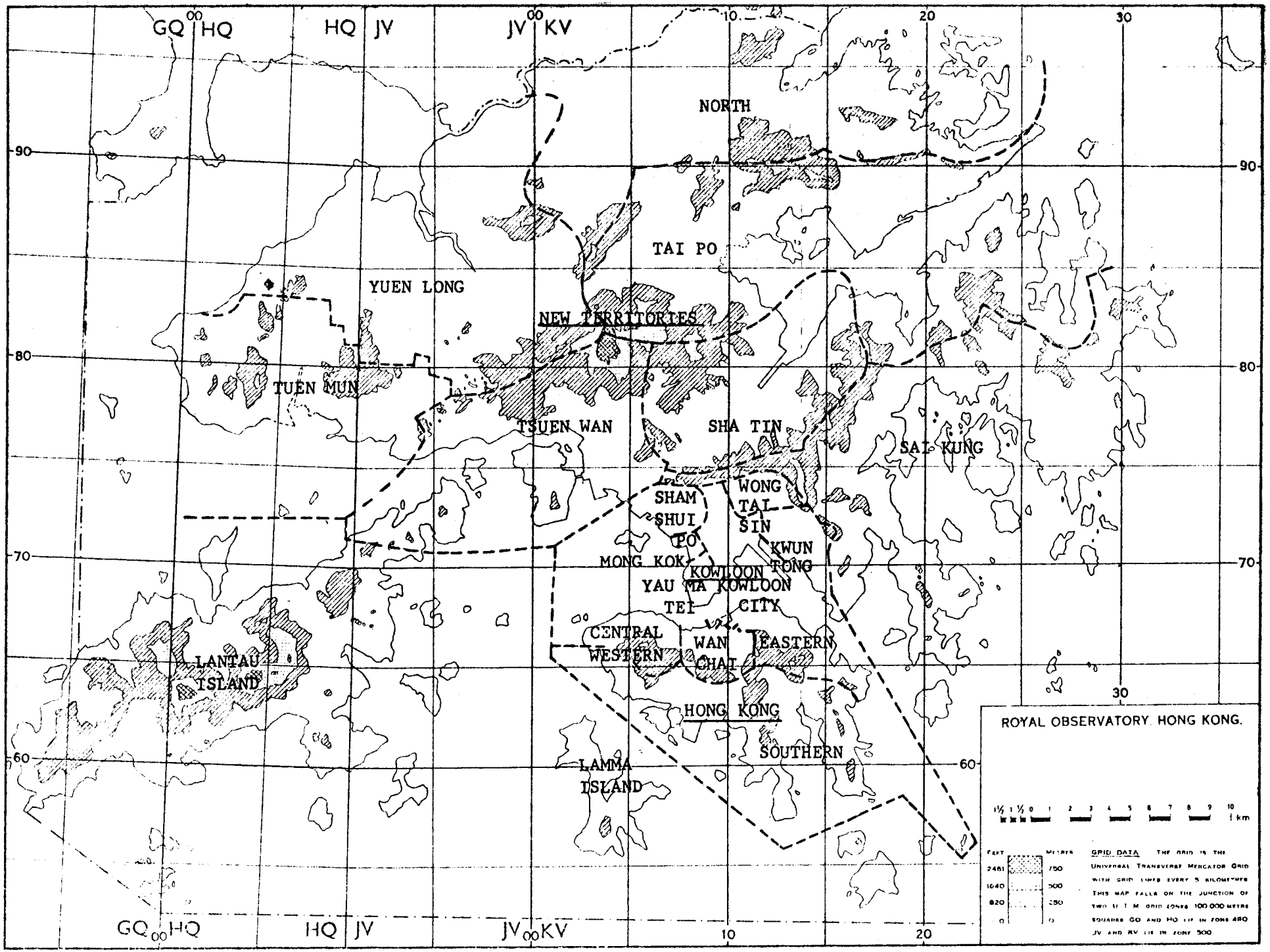


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Fig. 4 Map of Hong Kong showing the city districts

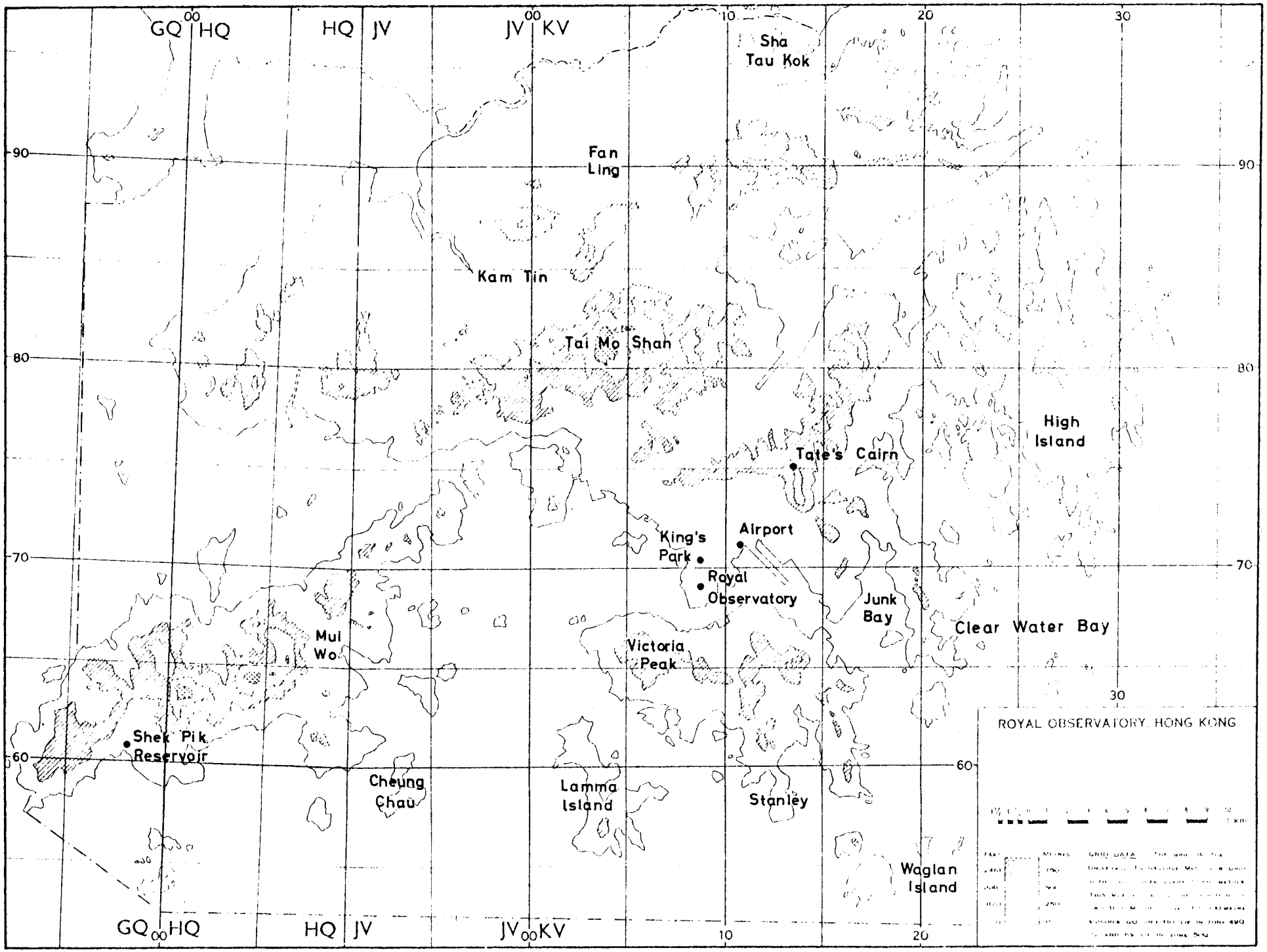

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Fig. 5 Locations of places in Hong Kong

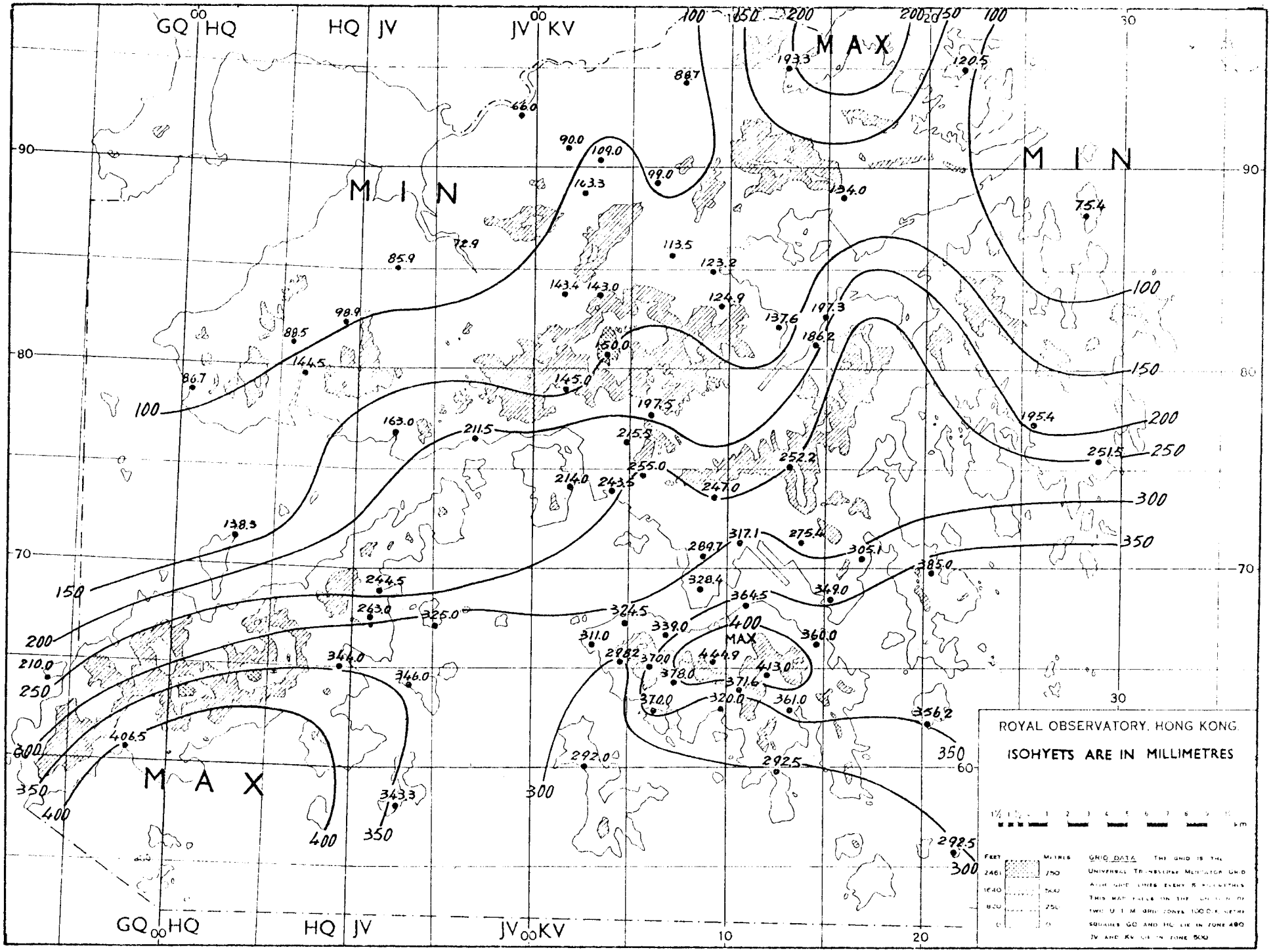

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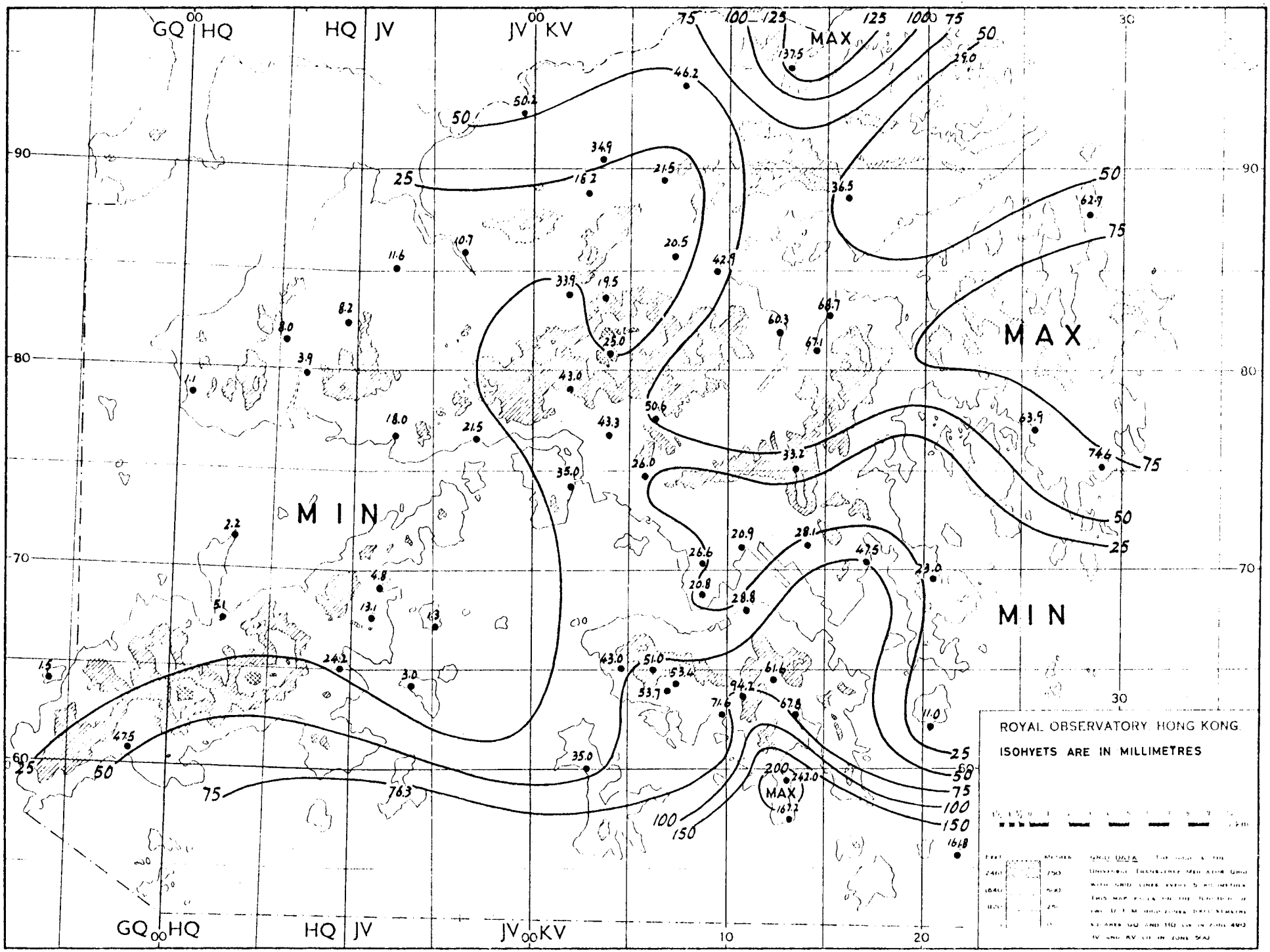
Fig. 6 Rainfall distribution map 3 p. m. 16 June to 3 p. m. 17 June 1983



R.O. 128

Fig. 7 Rainfall distribution map 3 p.m. 17 June to 3 p.m. 18 June 1983.

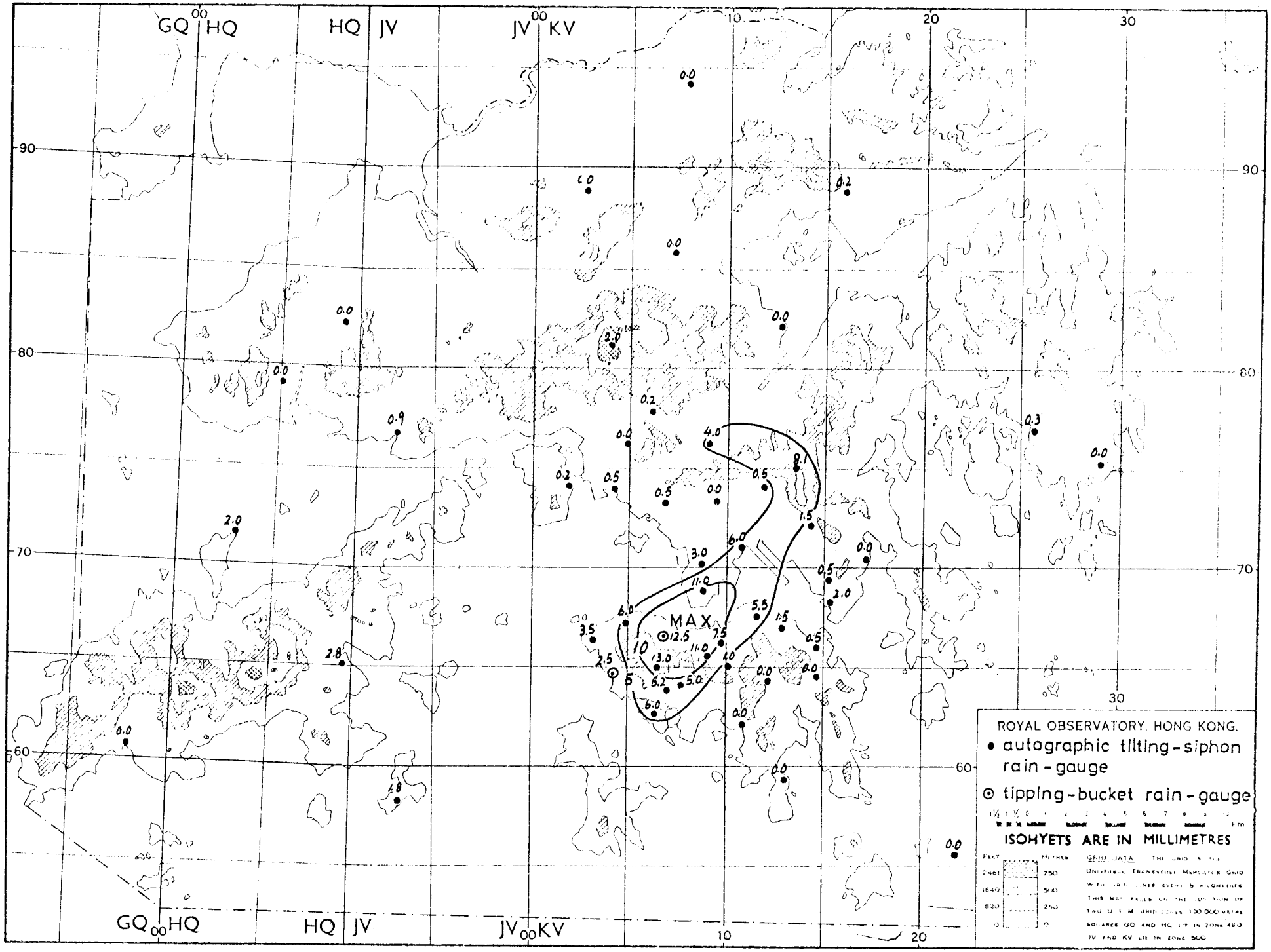


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Fig. 8(i) Hourly rainfall map ending at 0100 H. K. Time, 17 June 1983

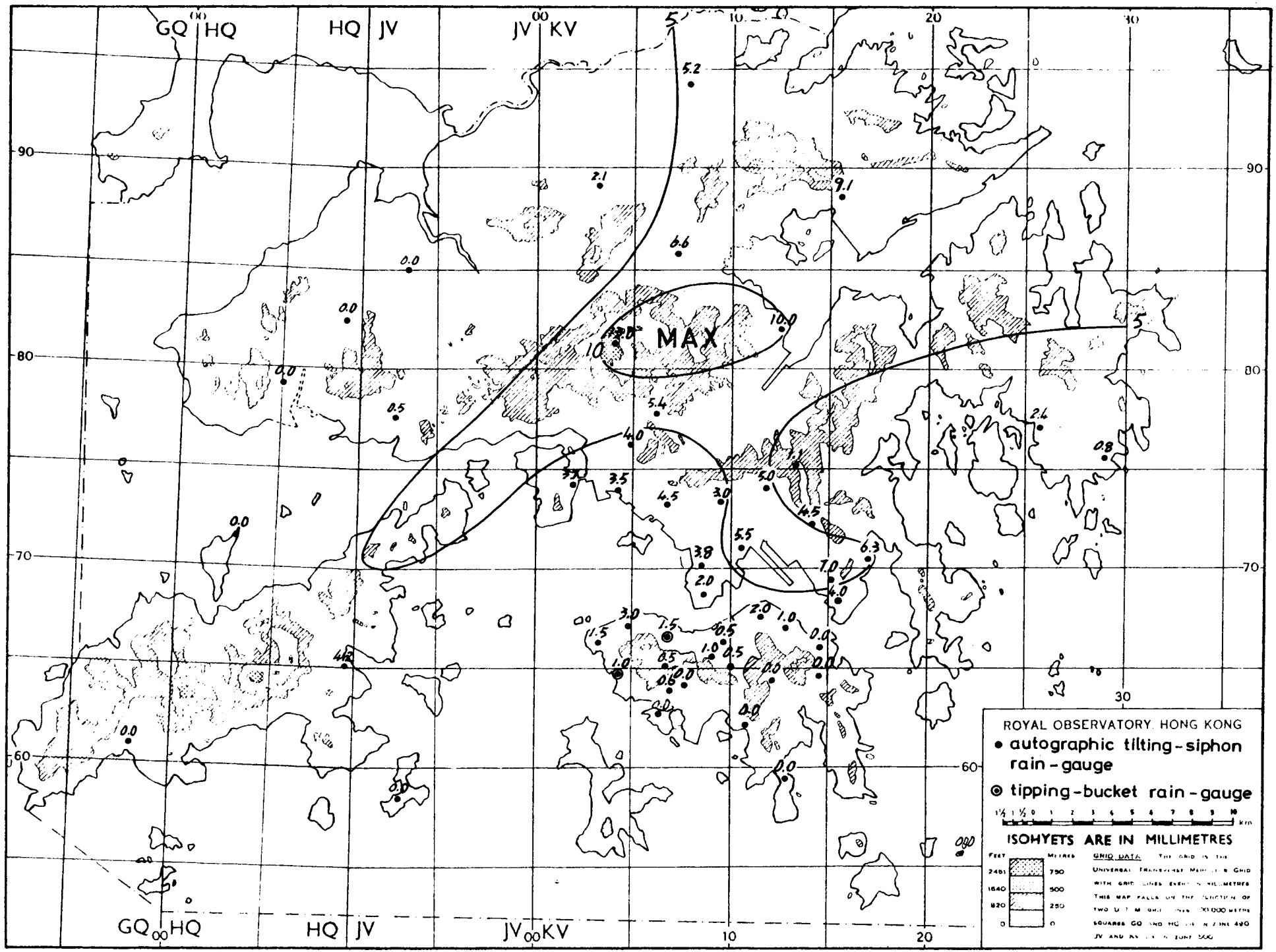

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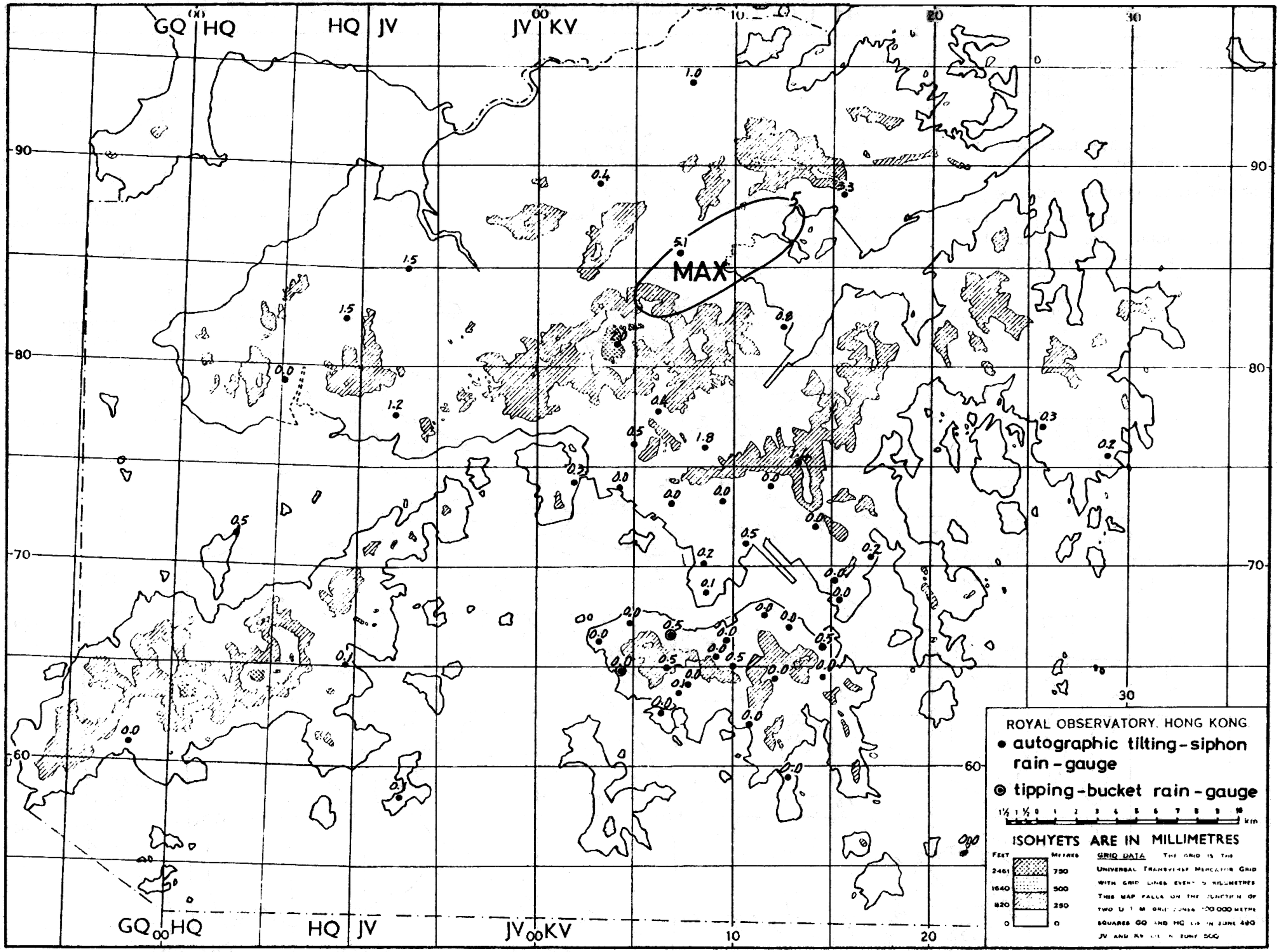
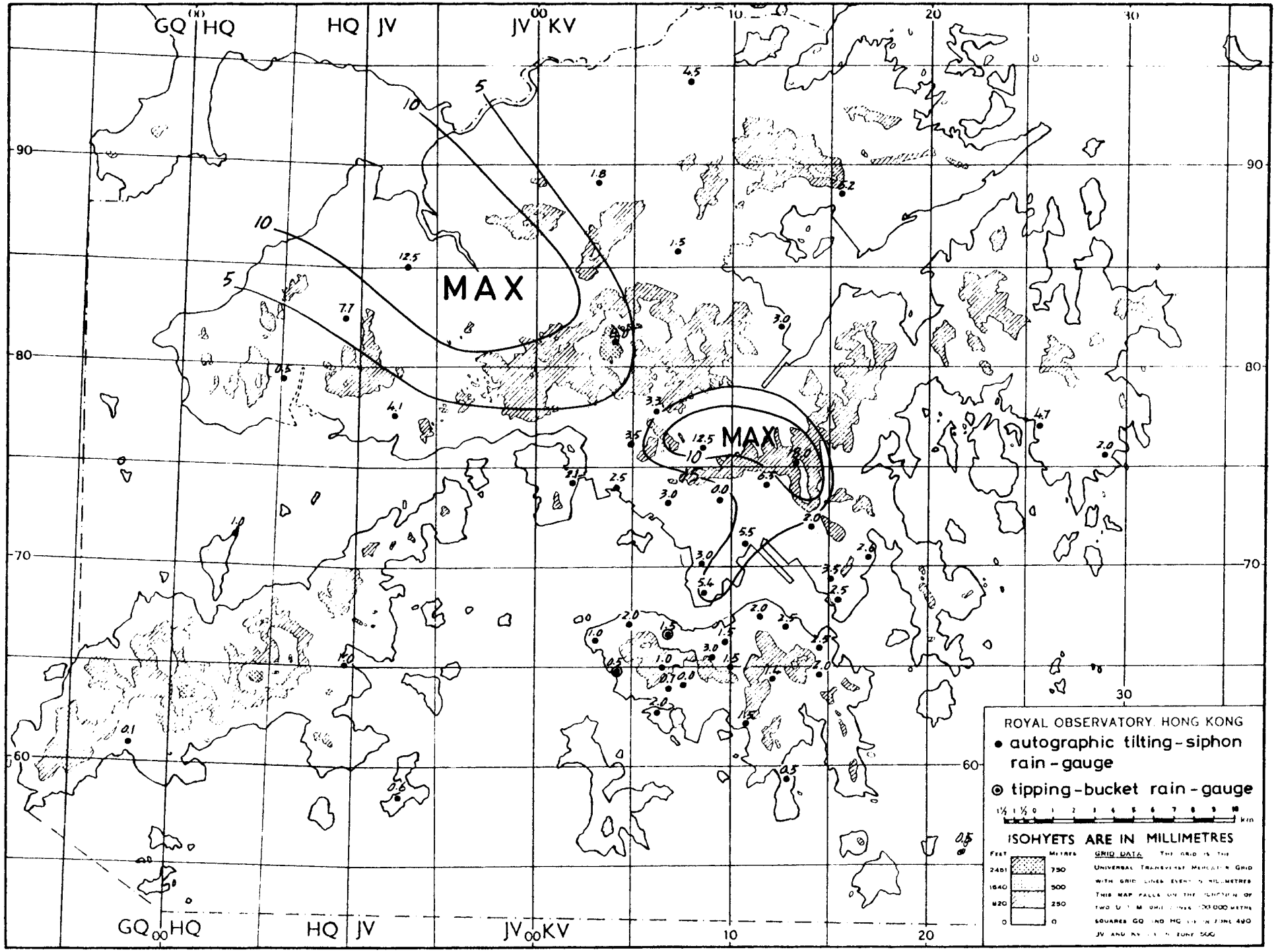
Fig. 8(ii) Hourly rainfall map ending at 0200 H.K. Time, 17 June 1983

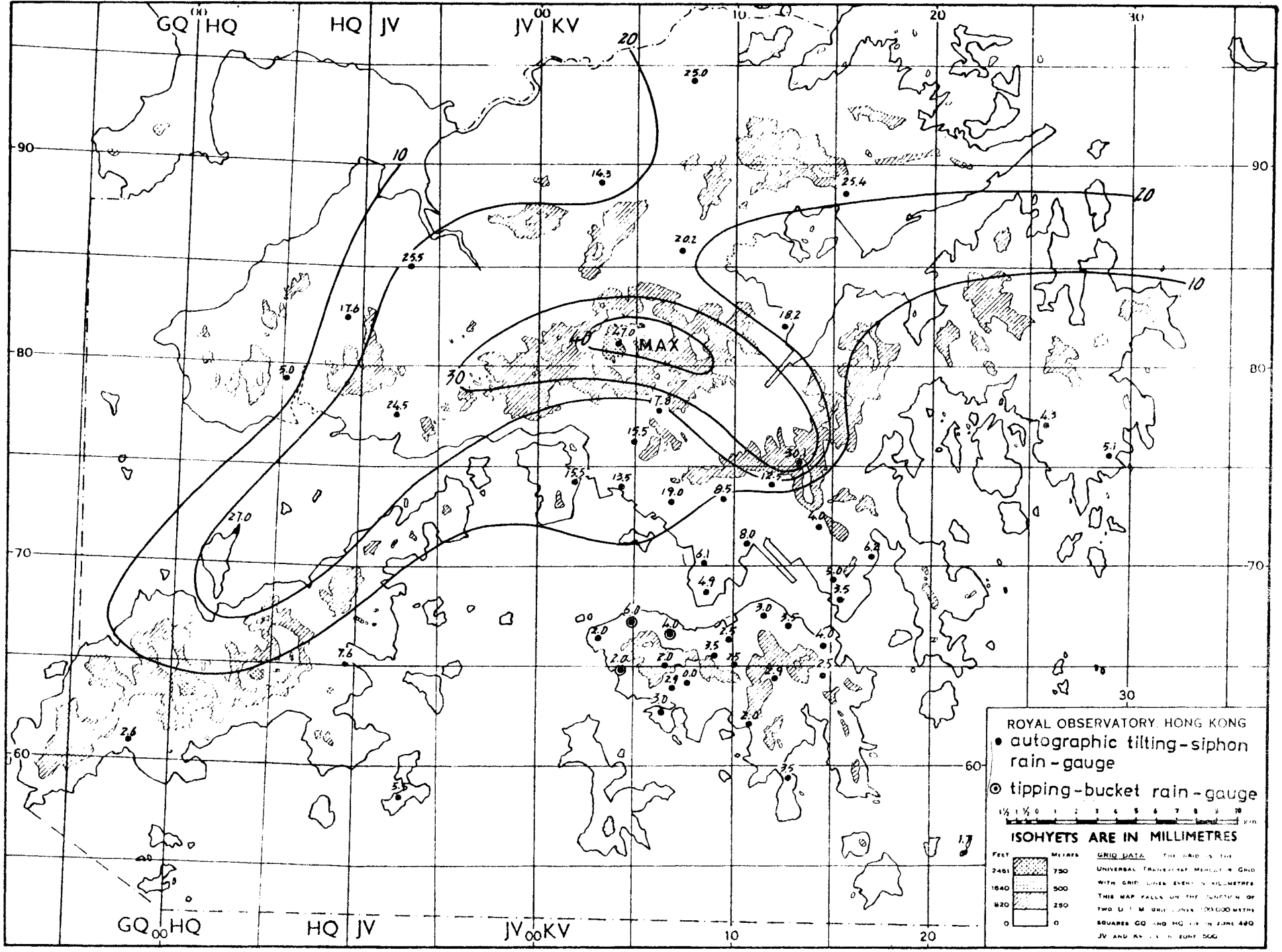


R.O. 128 **Fig. 8 (iii) Hourly rainfall map ending at 0300 H.K. Time, 17 June 1983**



R.O. 128

Fig. 8 (iv) Hourly rainfall map ending at 0400 H.K. Time, 17 June 1983



R.O. 128 **Fig. 8 (v) Hourly rainfall map ending at 0500 H.K. Time, 17 June 1983**

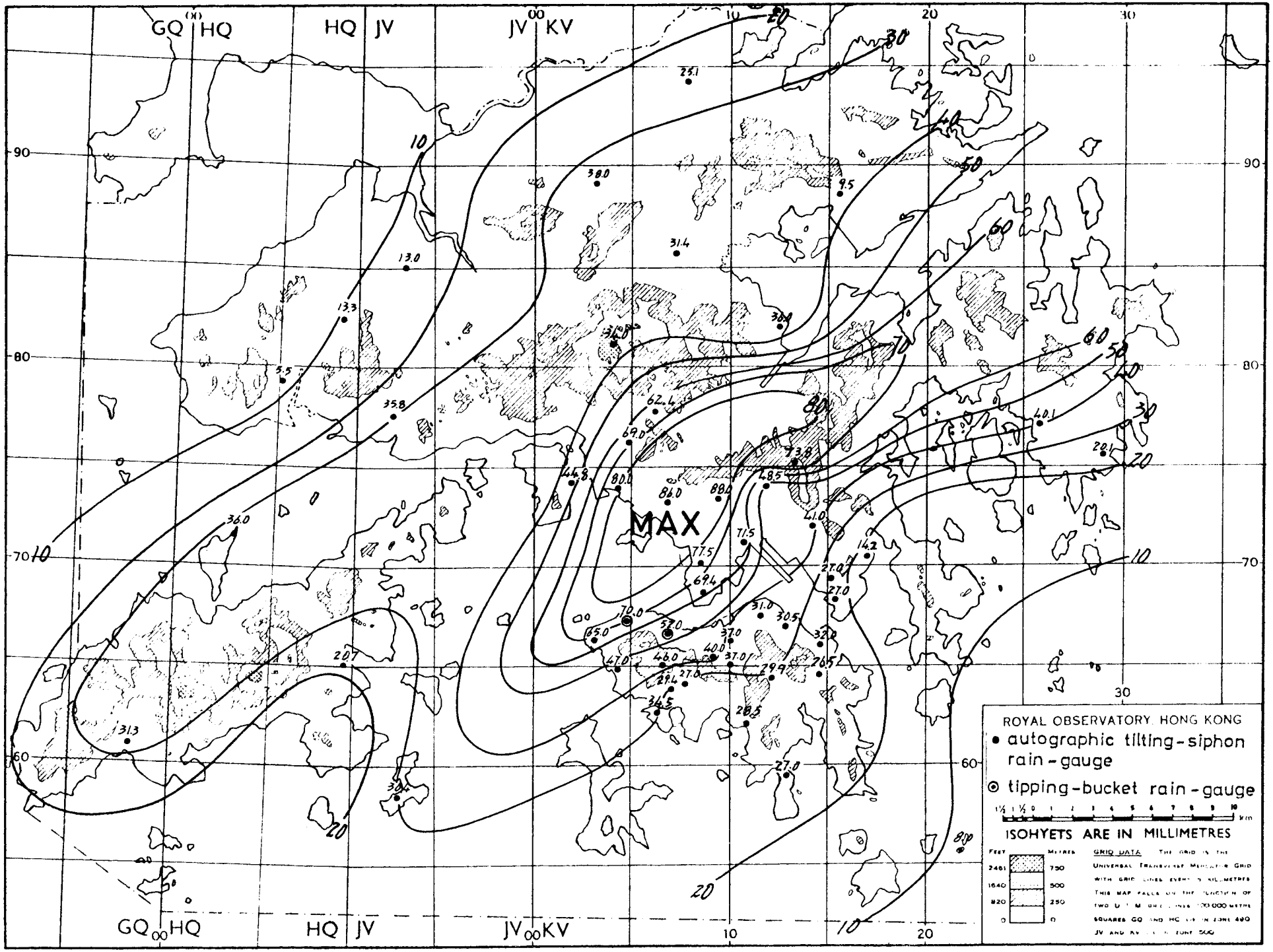


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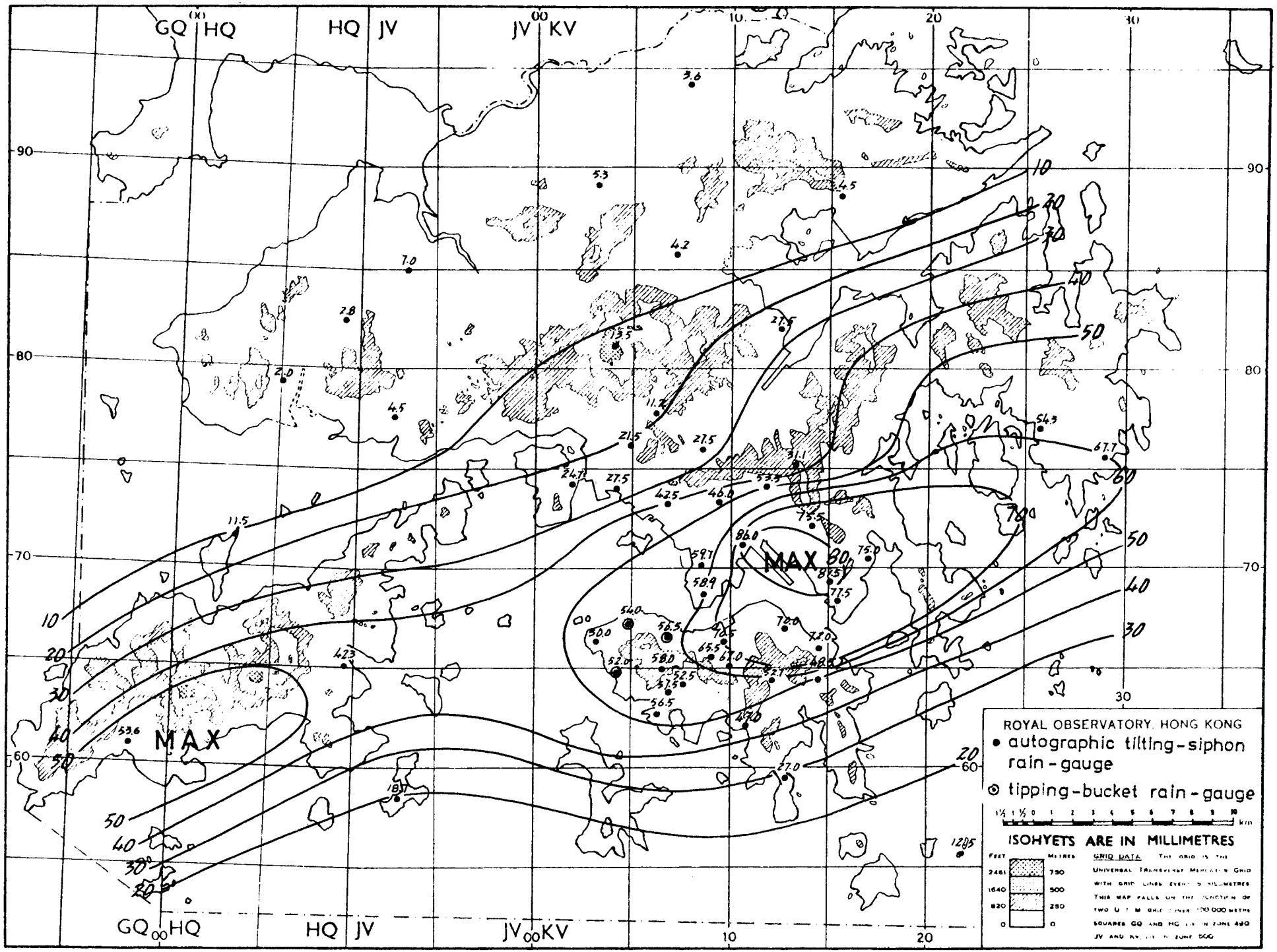
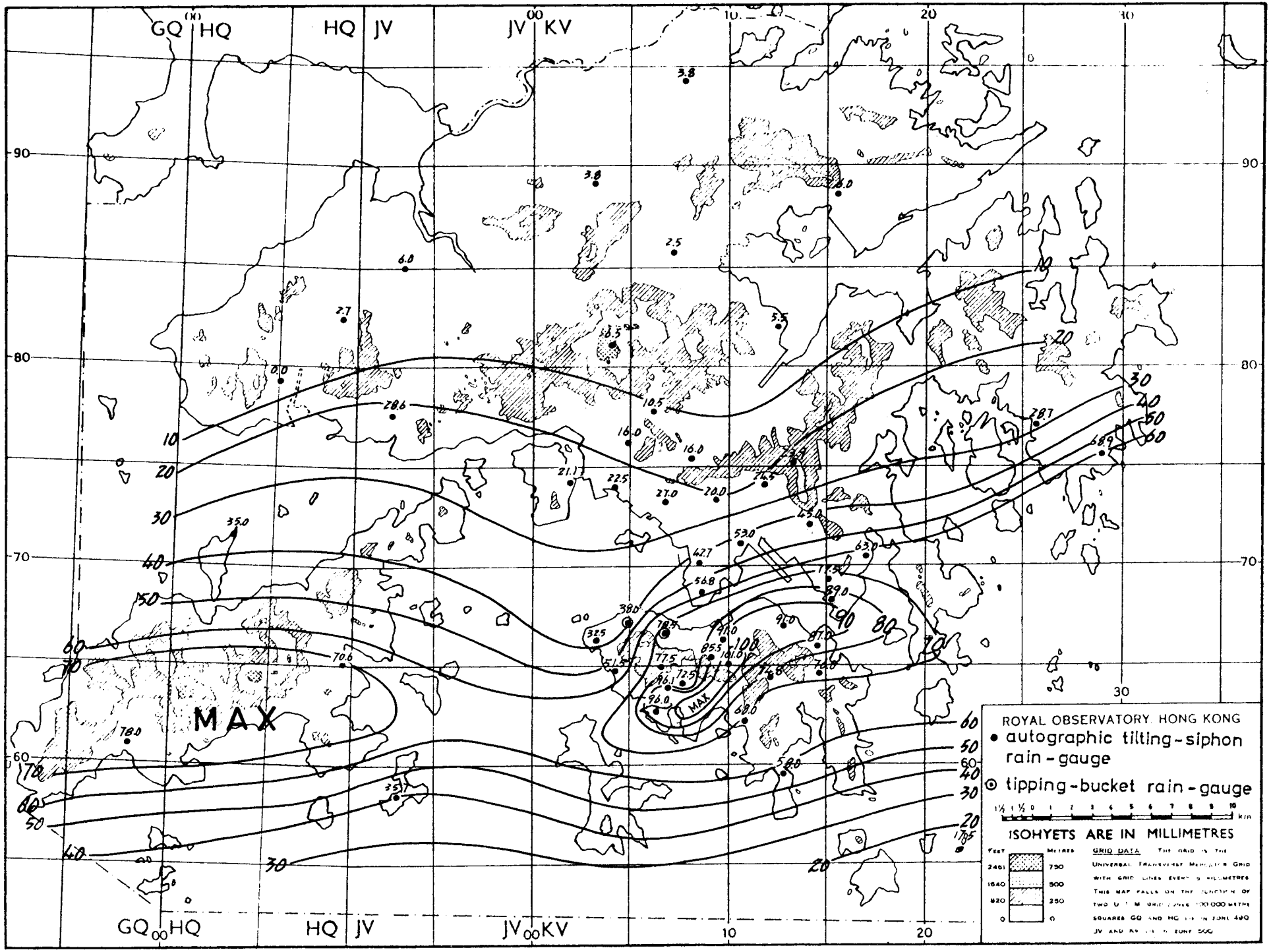
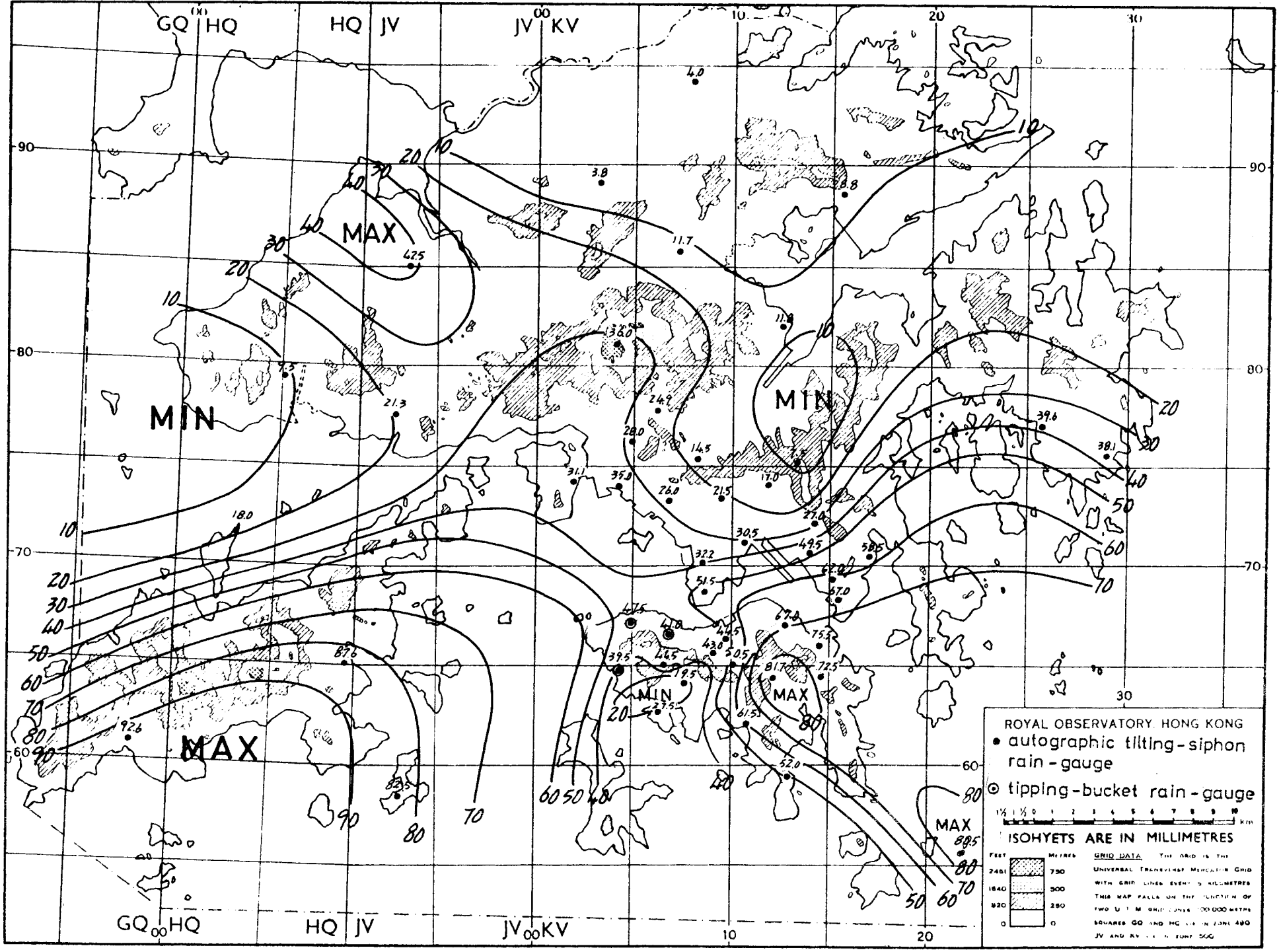
Fig. 8 (vi) Hourly rainfall map ending at 0600 H.K. Time, 17 June 1983



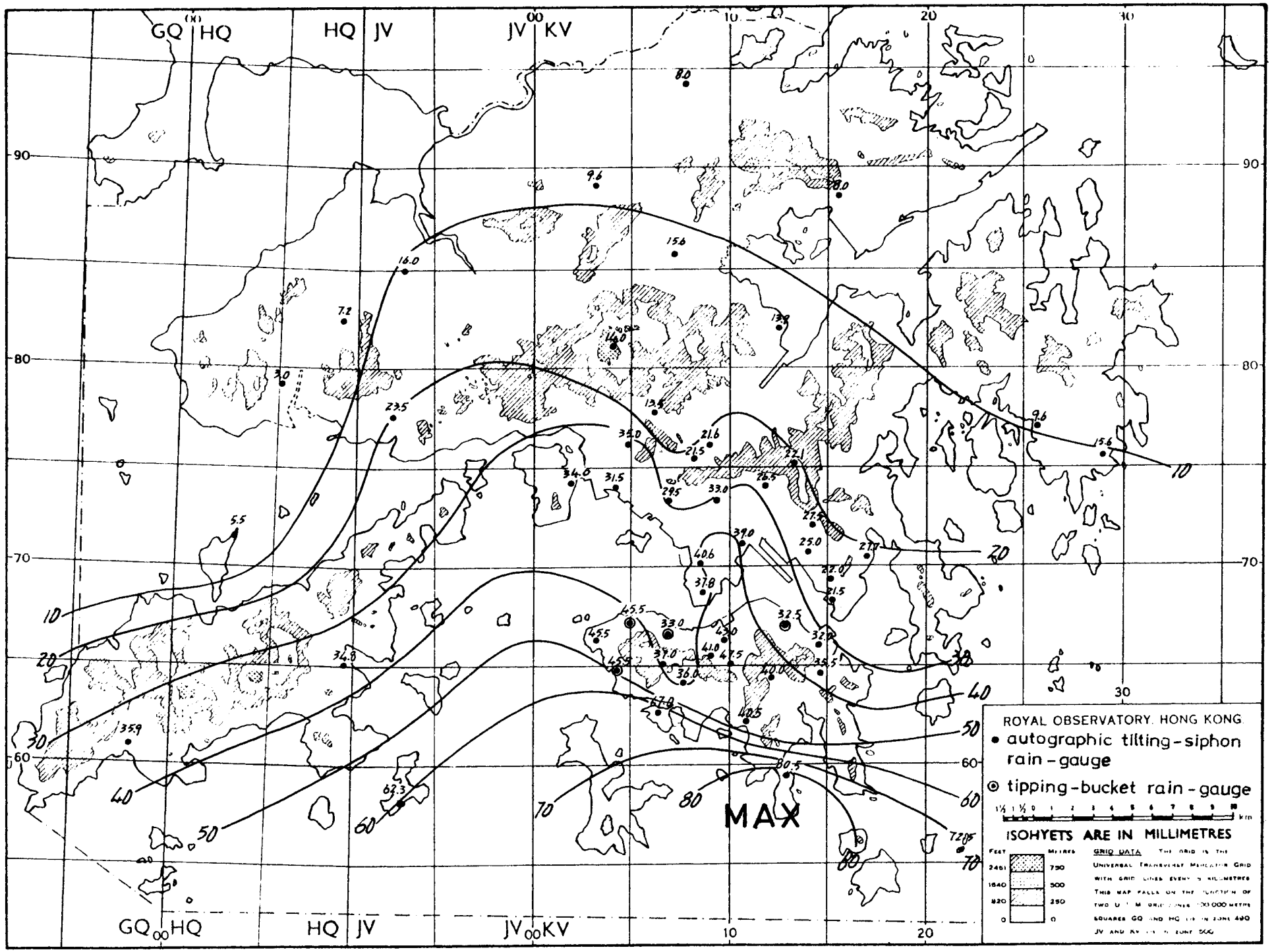
R.O. 128 **Fig. 8 (vii) Hourly rainfall map ending at 0700 H. K. Time, 17 June 1983**



R.O. 128 Fig. 8 (viii) Hourly rainfall map ending at 0800 H. K. Time, 17 June 1983



R.O. 128 **Fig. 8 (ix) Hourly rainfall map ending at 0900 H. K. Time, 17 June 1983**



R.O. 128 **Fig. 8 (x) Hourly rainfall map ending at 1000 H. K. Time, 17 June 1983**

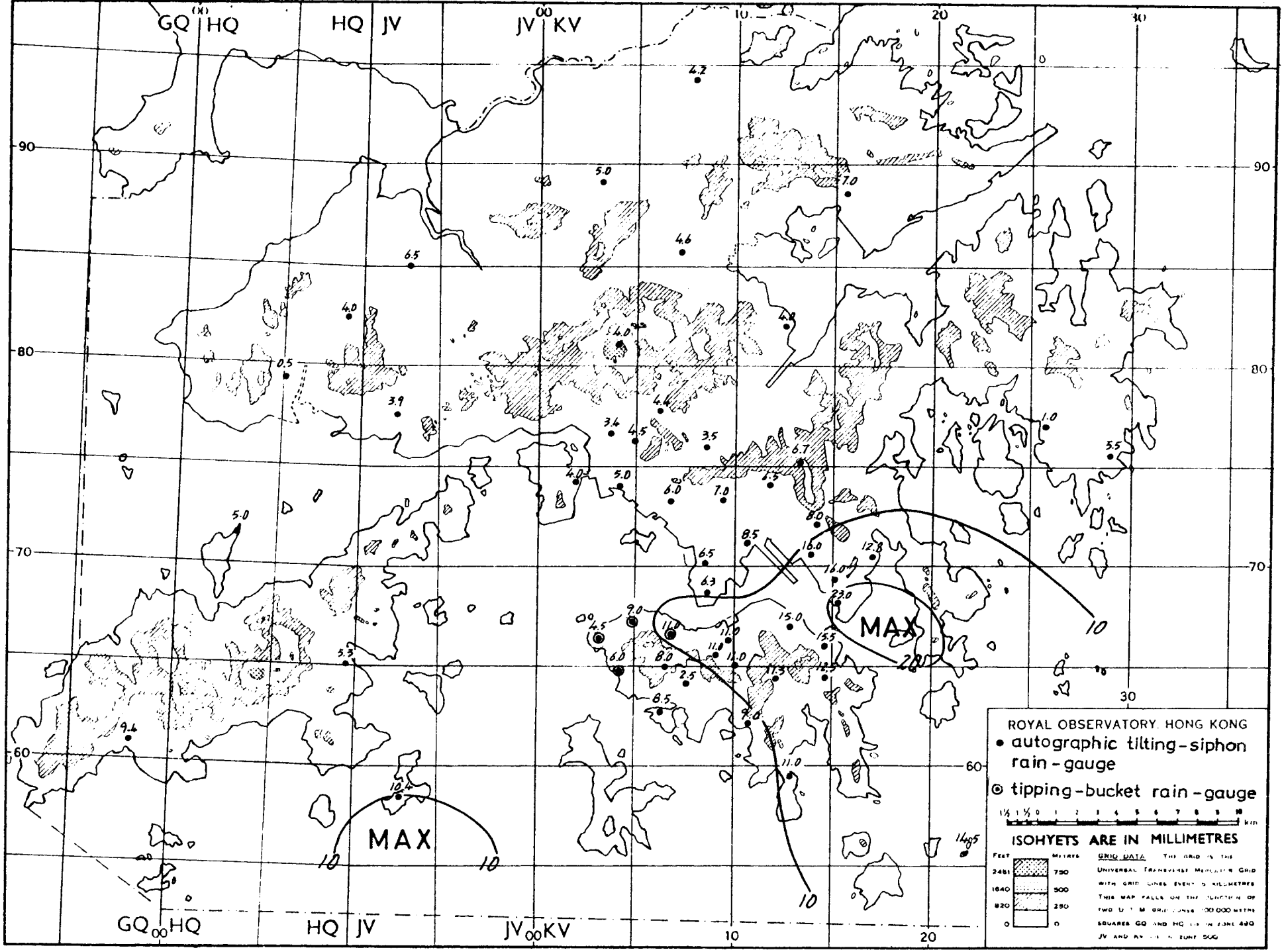


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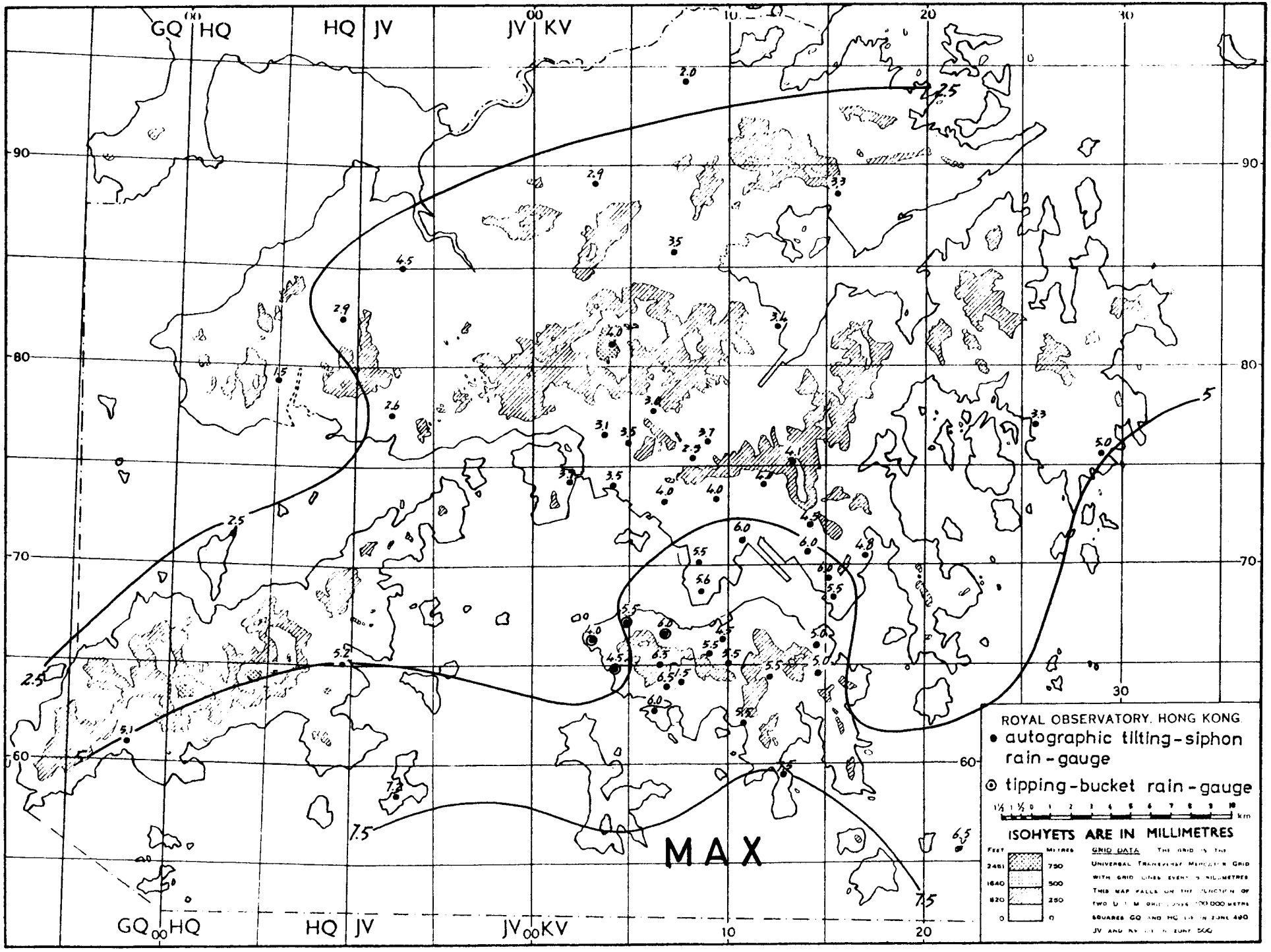
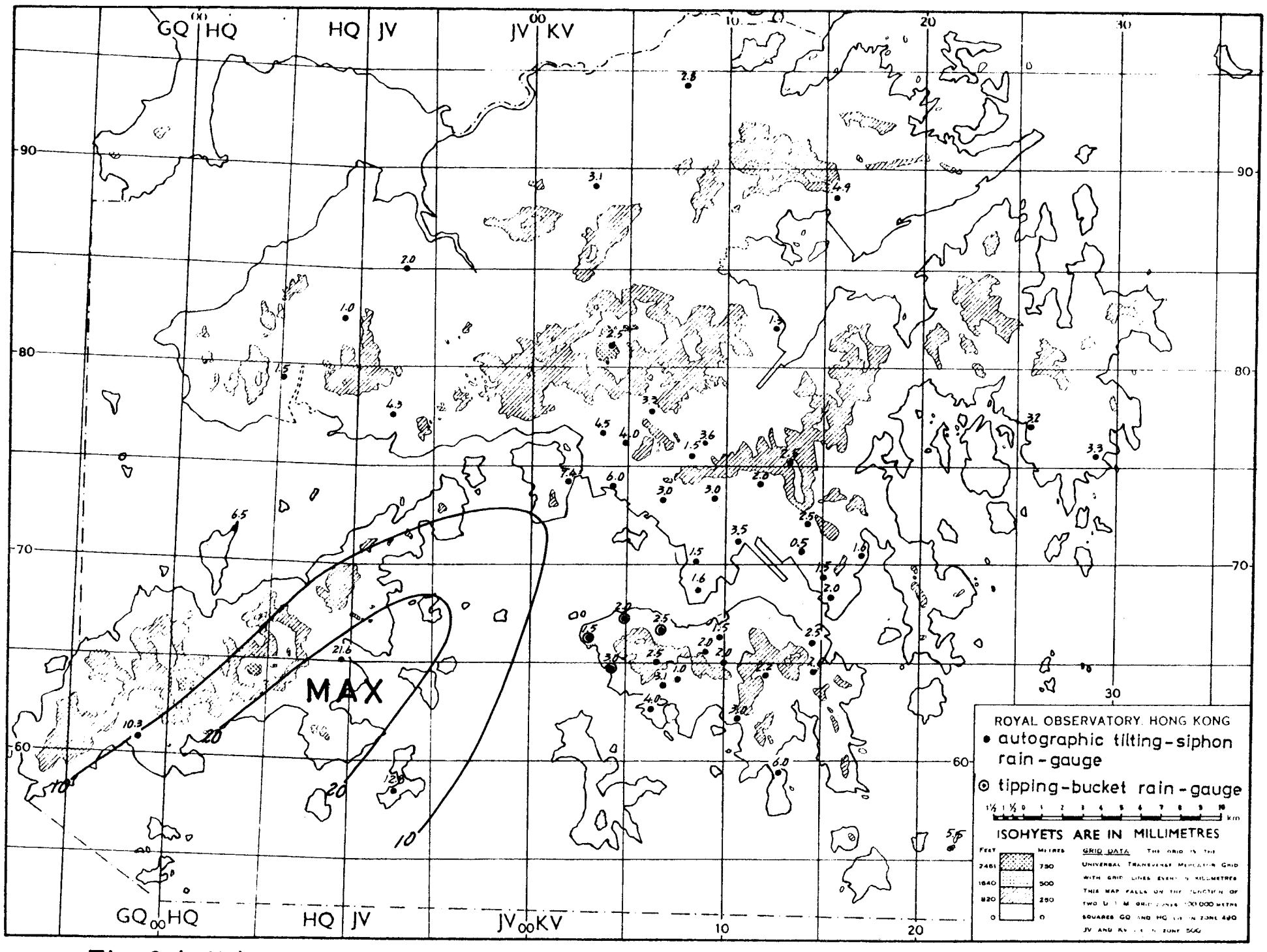
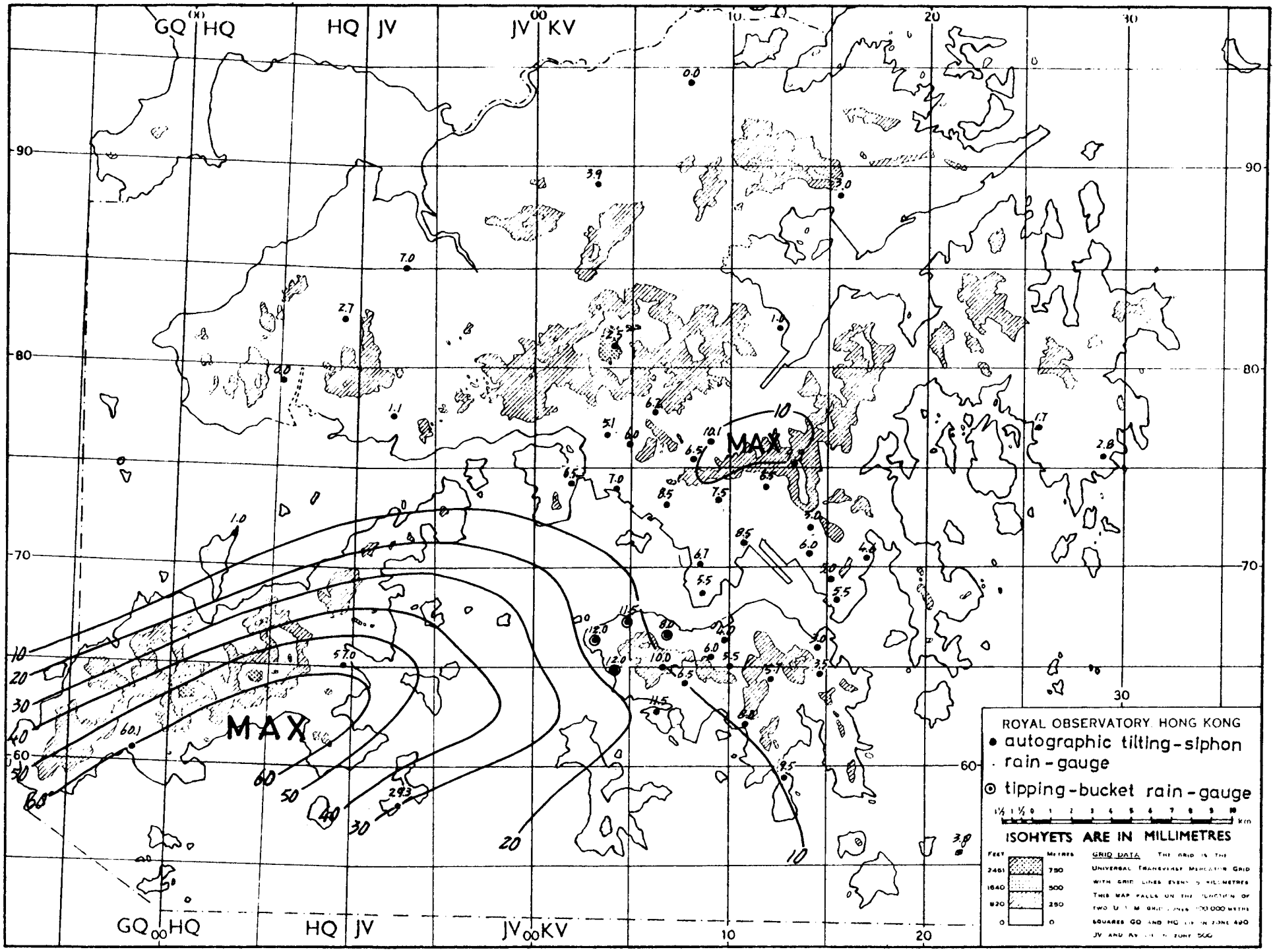
Fig. 8 (xi) Hourly rainfall map ending at 1100 H.K. Time, 17 June 1983



R.O. 128 Fig. 8 (xii) Hourly rainfall map ending at 1200 H. K. Time, 17 June 1983



R.O. 128 Fig. 8 (xiii) Hourly rainfall map ending at 1300 H. K. Time, 17 June 1983



R.O. 128 **Fig. 8 (xiv) Hourly rainfall map ending at 1400 H.K. Time, 17 June 1983**

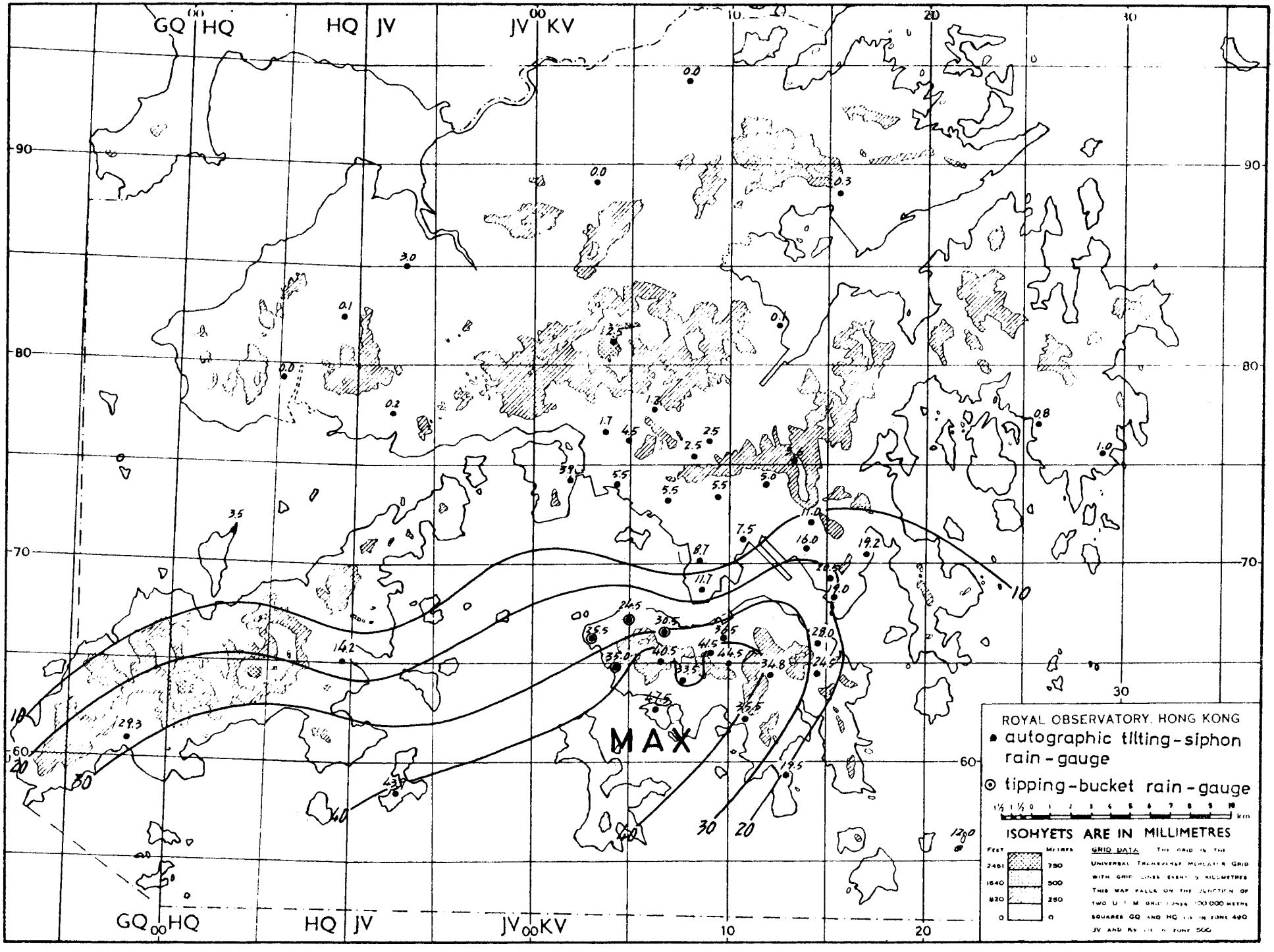


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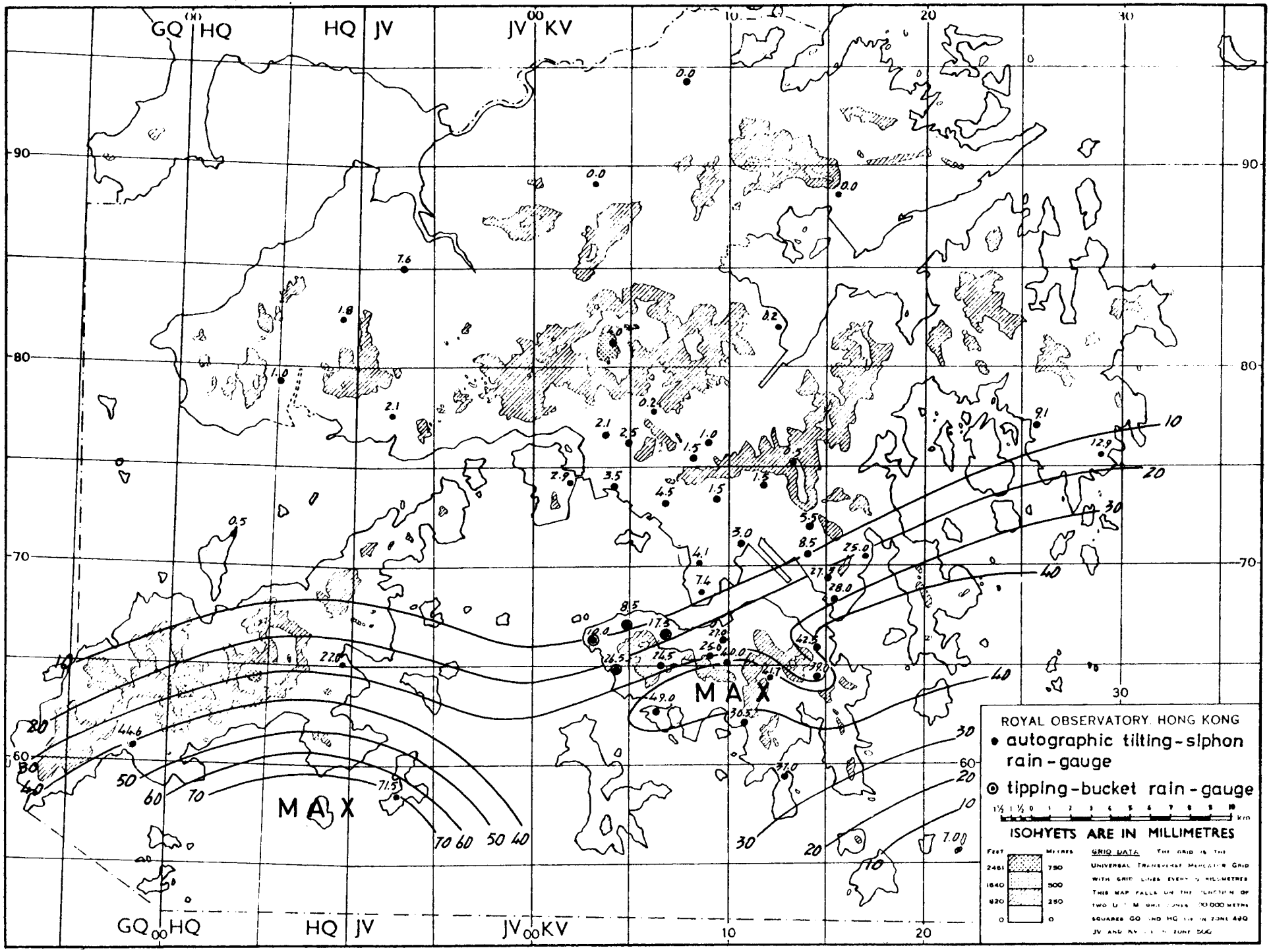
Fig. 8 (xv) Hourly rainfall map ending at 1500 H.K. Time, 17 June 1983



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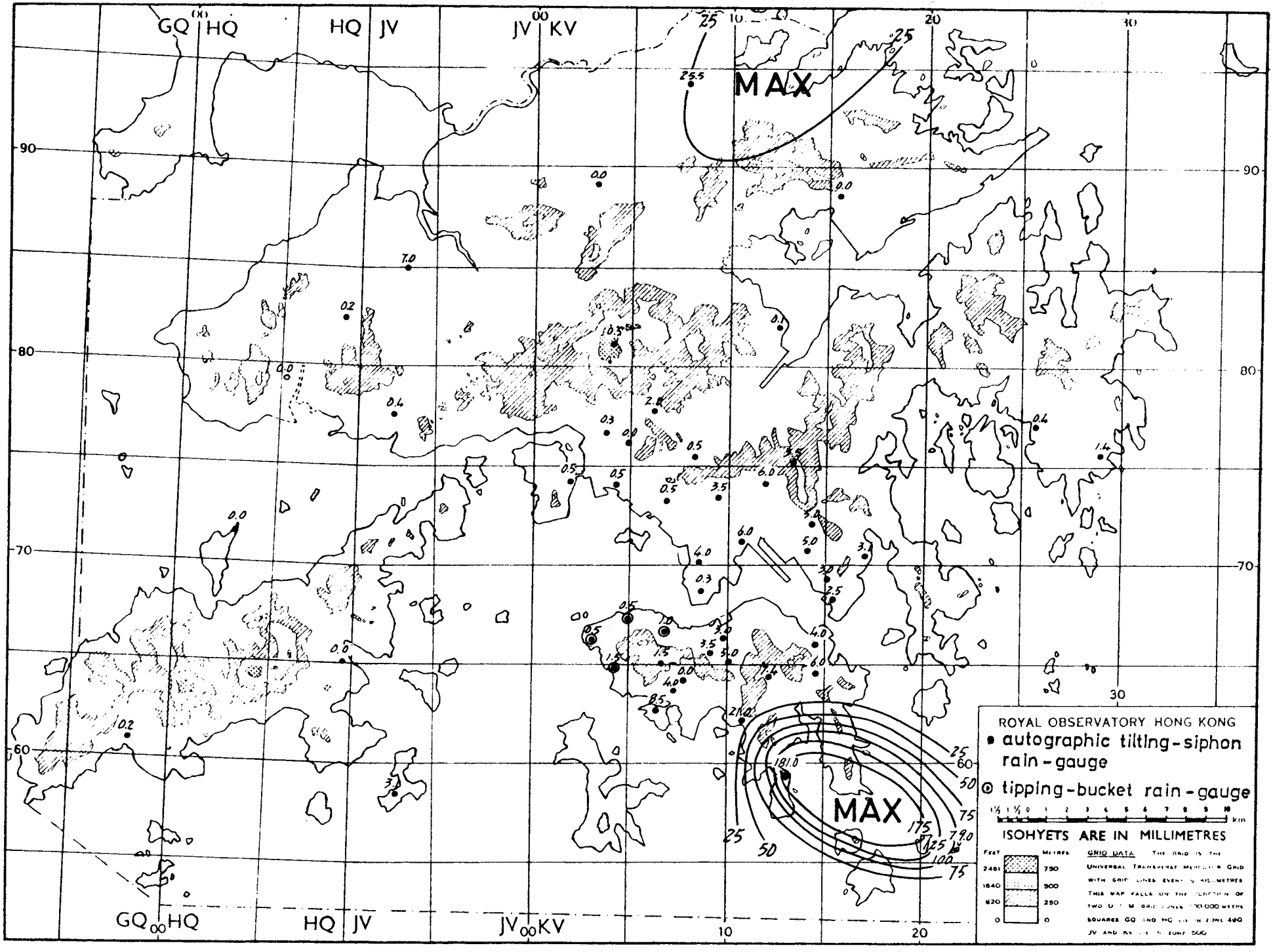
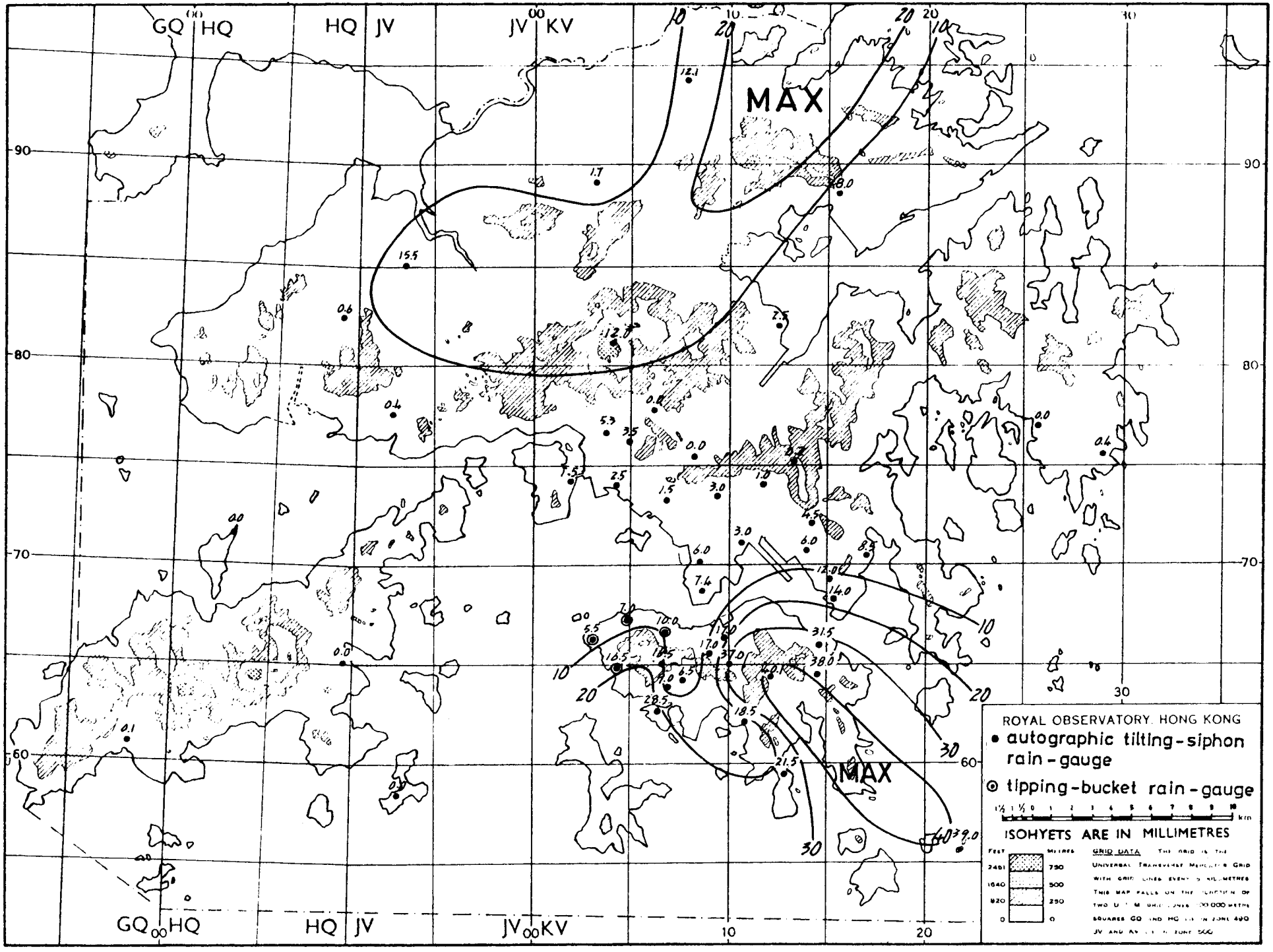
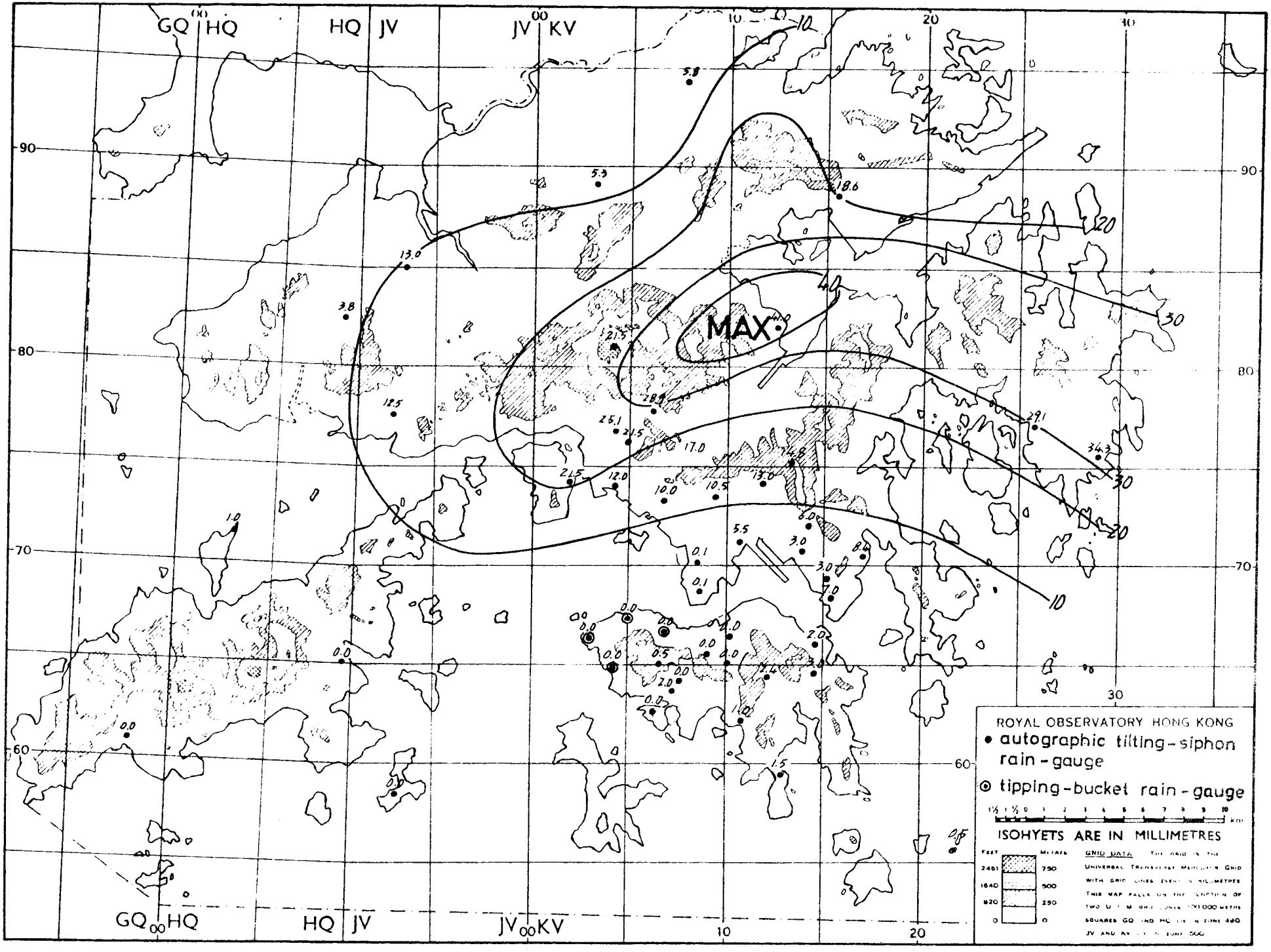


R.O. 128 **Fig. 8 (xvii) Hourly rainfall map ending at 1700 H. K. Time, 17 June 1983**



R.O. 128 **Fig. 8 (xviii) Hourly rainfall map ending at 1800 H.K. Time, 17 June 1983**



R.O. 128 **Fig. 8 (xix) Hourly rainfall map ending at 1900 H. K. Time, 17 June 1983**

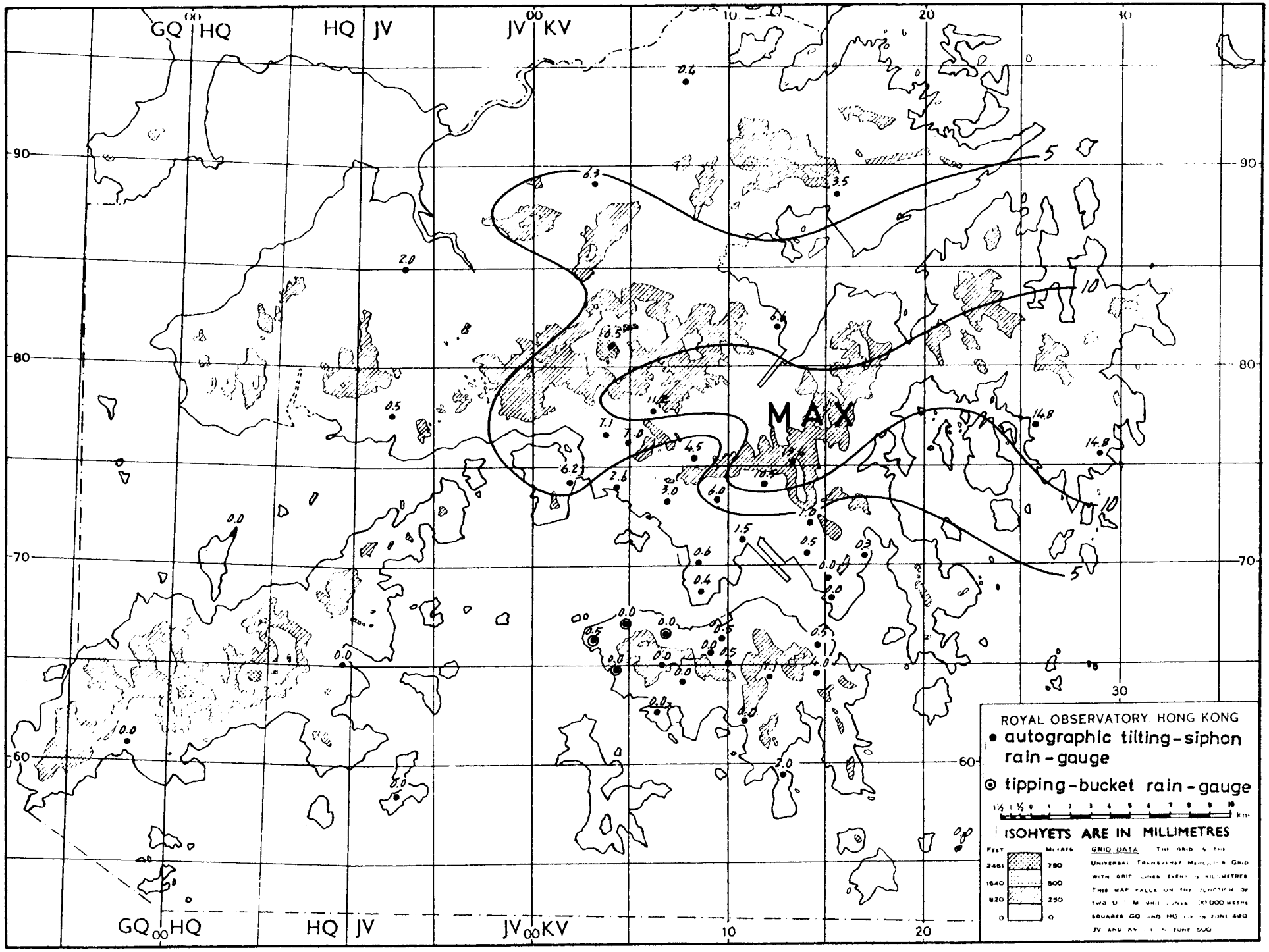


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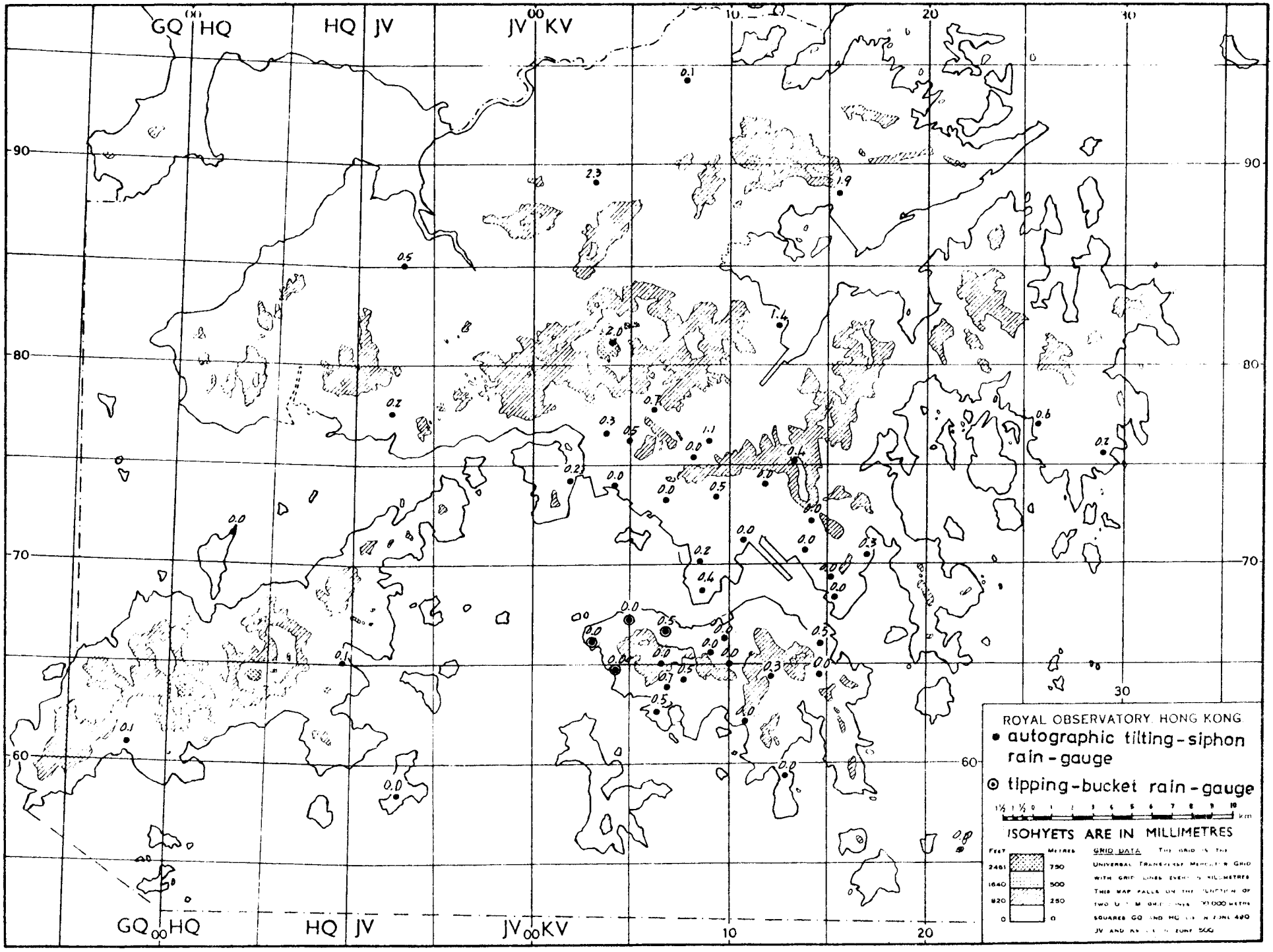
Fig. 8 (xx) Hourly rainfall map ending at 2000 H. K. Time, 17 June 1983



R.O. 128 **Fig. 8 (xxi) Hourly rainfall map ending at 2100 H. K. Time, 17 June 1983**

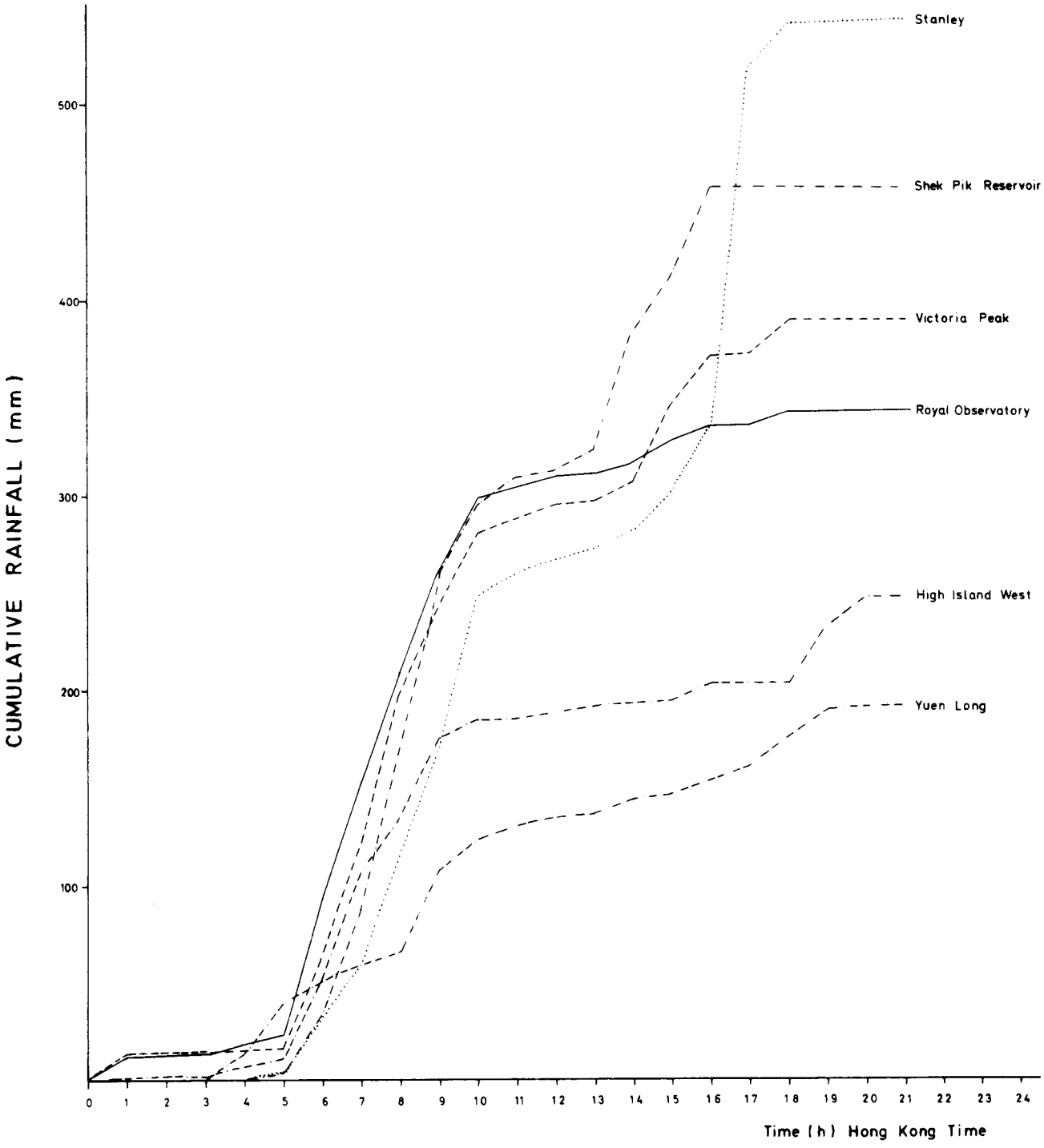


Fig. 9 Mass curves at various locations of Hong Kong, 17 June 1983

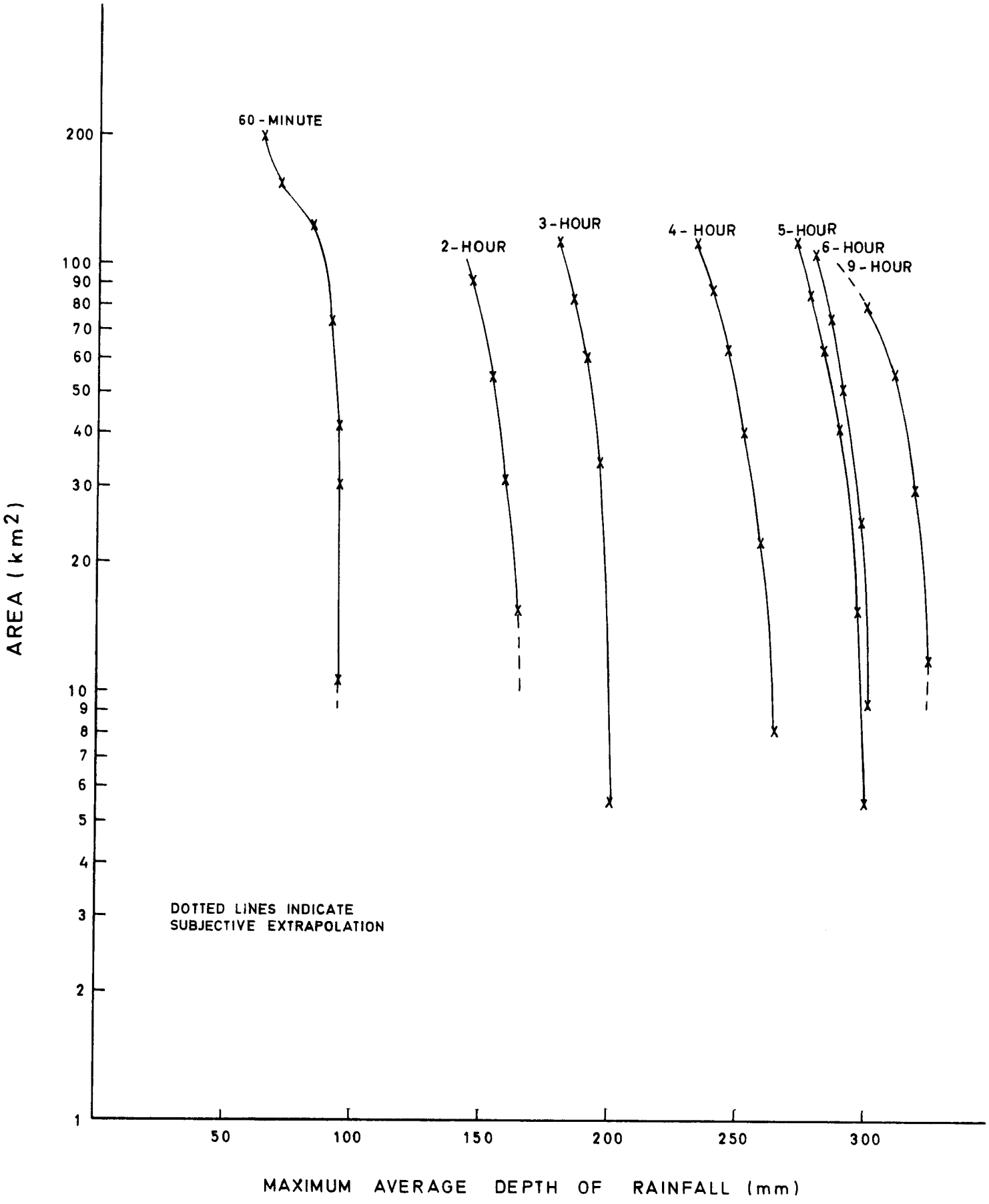


Fig.10 Depth-area-duration curves for the rainstorms on 17 June 1983

TABLE 1. INTENSITIES OF THE HEAVY RAIN ON 17 JUNE 1983 COMPARED WITH PREVIOUS ANNUAL MAXIMUM RECORDS

Duration	Time of Occurrence	Rainfall Amount mm	Intensity mm h^{-1}	Rank	Return[1] period yr	Remarks
15 seconds	0610H	-	234.0	20	< 5	1953-1982. Recorded at King's Park.
15 minutes	0700H - 0715H	32.0	128.0	10	< 5	1947-1982.
30 "	0650H - 0720H	53.0	106.0	8	<5	"
60 "	0530H - 0630H	83.5	83.5	12	<5	"
120 "	0525H - 0725H	159.5	79.8	3	15	"
240 "	0530H - 0930H	236.5	59.1	2	21	"
1 hour[2]	0500H - 0600H	69.4	69.4	>30	<5	1884-1939, 1947-1982
2 hours	0500H - 0700H	128.3	64.2	11	<10	" "
4 "	0500H - 0900H	236.4	59.1	5	30	" "
6 "	0500H - 1100H	280.7	46.8	5	26	" "
8 "	0400H - 1200H	291.2	36.4	5	18	" "
12 "	0400H - 1600H	317.4	26.5	5	15	" "

Notes : (1) Return periods were estimated from values obtained by Ieterson and Kwong (1981)
(2) Clock hour
(3) Civil day

TABLE 2. MAXIMUM RATE OF RAINFALL RECORDED BY THE JARDI RECORDERS, 17 JUNE 1983

	Rate ($mm\ h^{-1}$)	Time
Royal Observatory	258	0616 H
King's Park Meteorological Station	234	0610 H
Airport Meteorological Office	228	0614 H
Tate's Cairn Radar Station	283	0635 H

TABLE 3. MAXIMUM SHORT-DURATION INTENSITIES DERIVED FROM THE NETWORK OF AUTOMATIC RAIN-GAUGES ON 17 JUNE 1983

Station	Station No.	Height above M.S.L. (m)	15-min Rainfall (mm)	Ending Time (HHMM)	30-min Rainfall (mm)	Ending Time (HHMM)	60-min Rainfall (mm)	Ending Time (HHMM)	120-min Rainfall (mm)	Ending Time (HHMM)
Royal Observatory	201	30	32.0	0715	53.0	0720	83.5	0630	159.5	0725
Aberdeen Lower Reservoir	10	85	43.4	0745	56.4	0745	96.1	0800	164.4	0815
Airport Met. Office	202	5	39.0	0610	71.0	0625	112.0	0630	168.0	0730
Cheung Chau Met. Stn.	234	70	31.8	1530	62.6	1545	95.8	0925	158.7	0940
Chinese University	351	120	21.0	0605	36.0	0605	50.0	0615	75.0	0615
Haven of Hope Hospital	324	25	22.0	0615	43.0	0630	75.0	0700	138.0	0800
High Island East	352	125	29.5	0745	50.0	0745	73.5	0810	136.6	0800
High Island West	350	85	25.0	0550	48.5	0605	75.0	0635	107.0	0735
Jubilee Reservoir	212	200	34.0	0550	50.0	0550	65.0	0610	83.0	0615
King's Park Met. Stn.	228	65	29.0	0600	56.0	0615	100.0	0615	146.0	0715
Shek Pik Reservoir	268	5	35.0	1520	54.0	0815	97.0	0815	174.0	0915
Silver Mine Bay Treat. Wk.	326	60	25.0	0815	41.0	0745	75.0	0815	136.0	0850
Stanley	H15*	30	60.5	1620	97.5	1625	181.5	1655	230.5	1730
Ta Kwu Ling Farm	283	5	21.0	1650	27.0	1710	37.0	0515	49.0	0615
Tai Lam Chung Reservoir	220	45	17.5	0515	28.5	0525	46.0	0535	61.2	0550
Tai Lung Farm	258	35	15.7	0540	25.5	0540	36.0	0540	54.0	0615
Tai Mei Tuk Pumping Stn.	341	10	25.0	0510	36.0	0520	53.5	0530	64.9	0600
Tai Mo Shan	N14*	950	-	-	29.5	0455	52.5	0515	86.0	0615
Tai Po Tau Treatment Wk.	302	105	19.0	0515	25.0	0515	37.3	0530	52.0	0605
Tai Tam Byewash	205	155	29.5	0835	50.0	0835	100.0	0835	167.5	0845
Tate's Cairn Radar Stn.	277	575	29.8	0545	46.0	0545	77.1	0545	119.8	0625
Tsing Yi Development Off.	305	25	18.0	0545	31.5	0600	51.0	0610	70.5	0645
Waglan Island	203	50	29.0	1645	51.0	1705	99.5	1720	153.0	1000
Yuen Long Police Stn.	N12*	45	-	-	18.5	0445	26.0	0515	58.5	1000

* automatic telemetering gauges. See Section 4 concerning derivation of maximum intensities.

TABLE 4. MAXIMUM AVERAGE DEPTH OF RAINFALL DURING THE RAINSTORMS ON 17 JUNE 1983

Area in sq. km	Duration						
	60-min	2-hour	3-hour	4-hour	5-hour	6-hour	9-hour
	mm	mm	mm	mm	mm	mm	mm
10	95	166	200	265	299	302	325
20	95	163	198	260	296	300	322
50	94	155	193	250	287	292	313
100	88	144	183	237	276	282	289

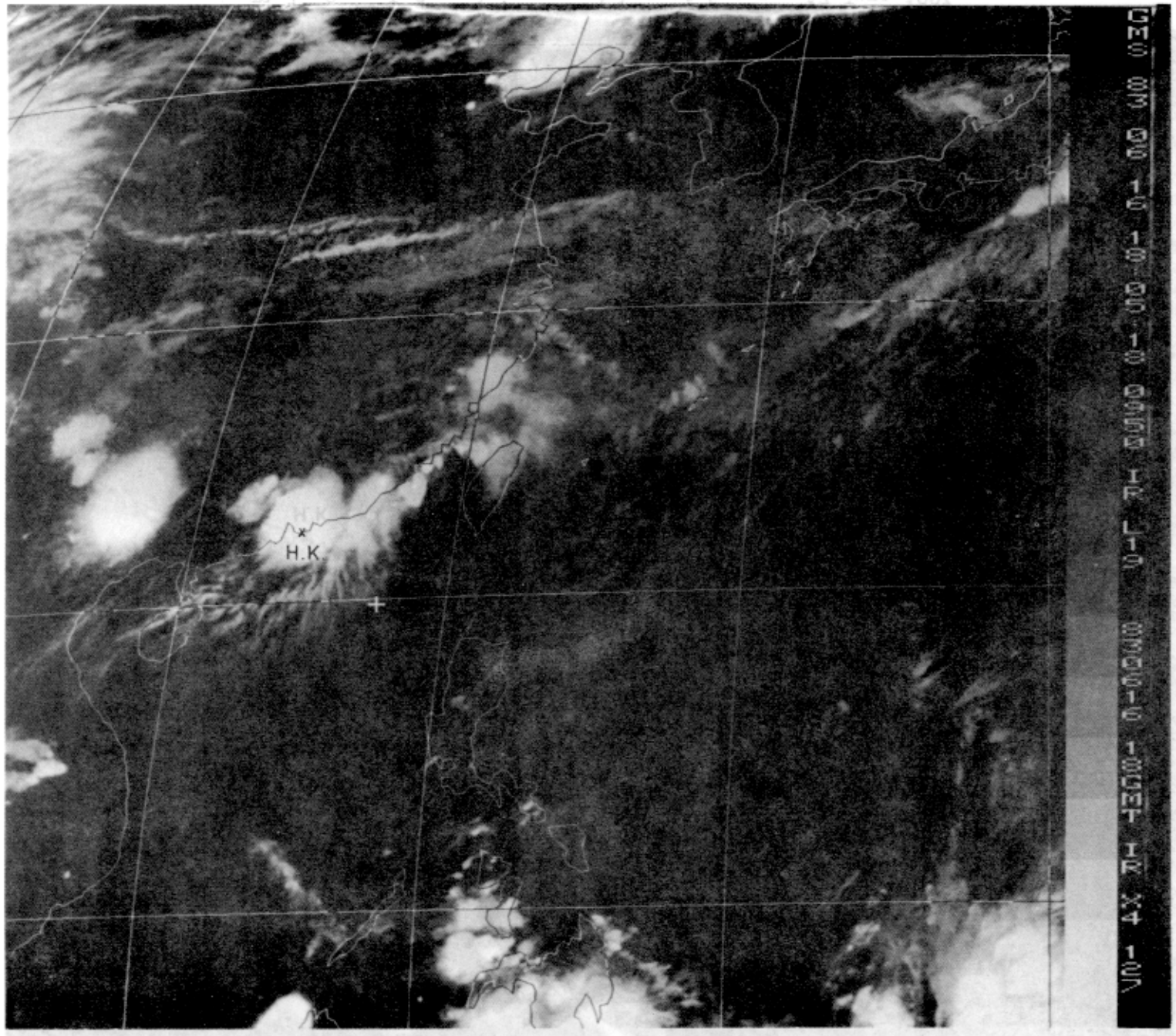


Plate 1. Infrared imagery taken at 2 a.m., 17 June 1983

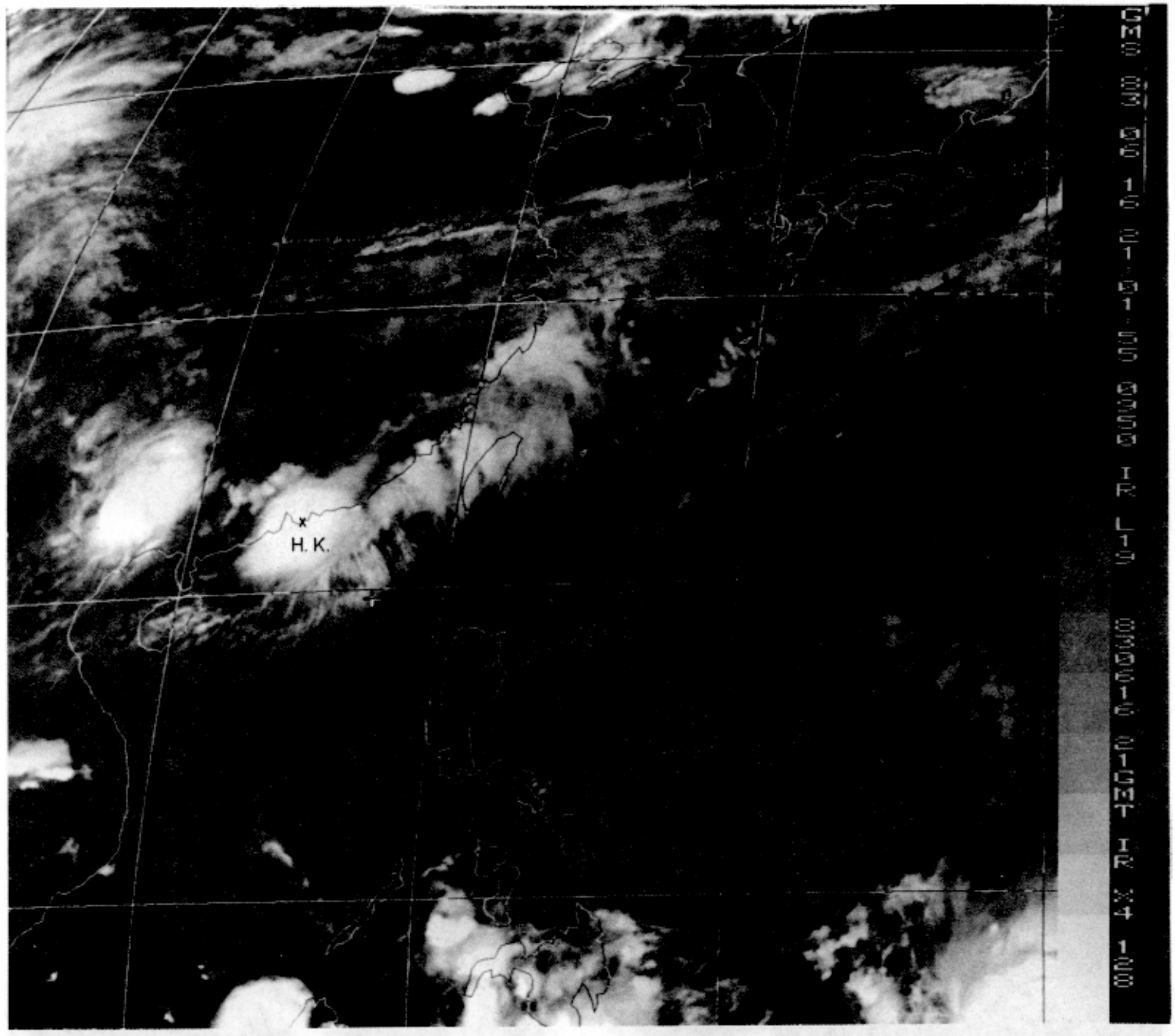


Plate 2. Infrared imagery taken at 5 a.m., 17 June 1983

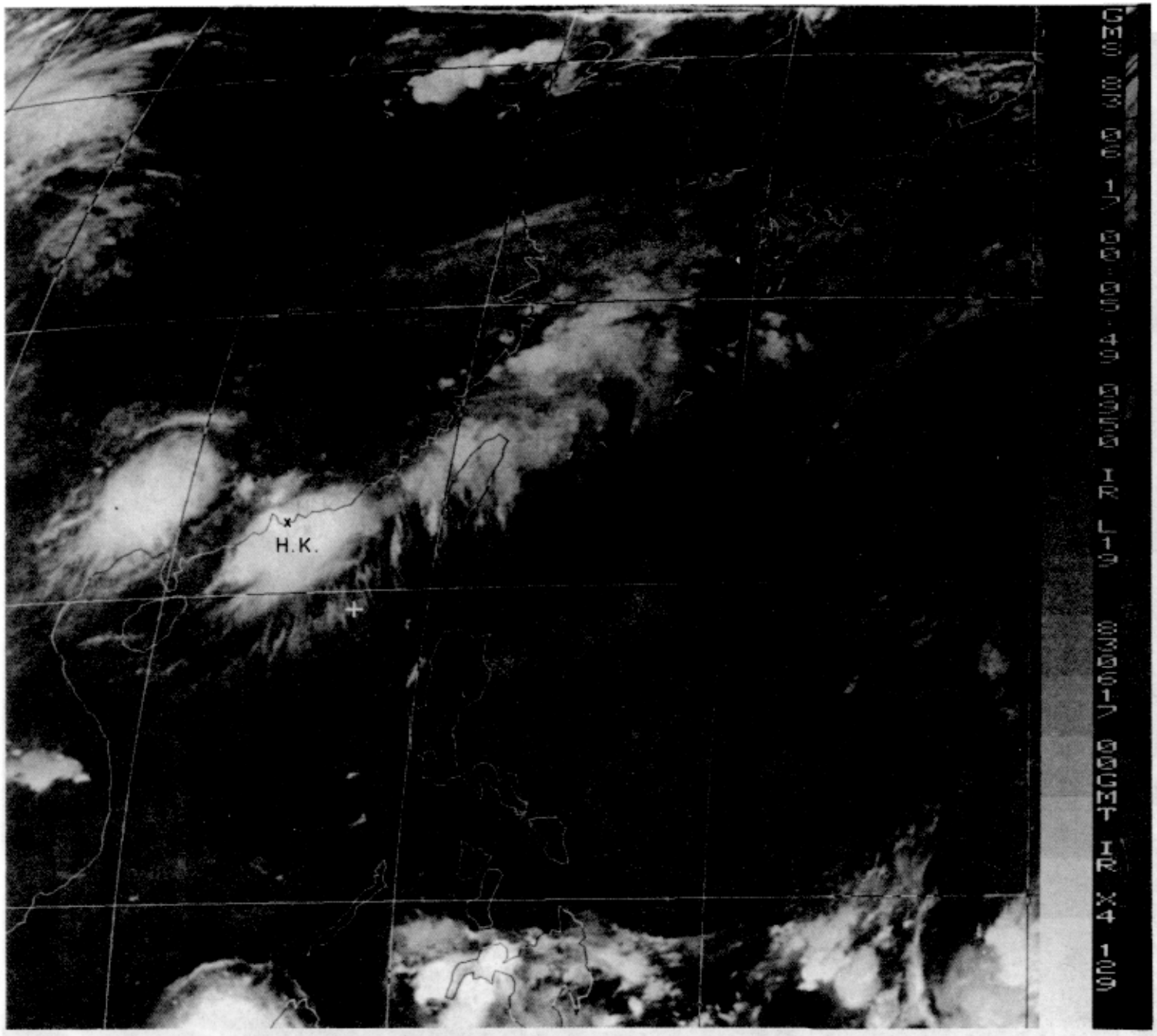


Plate 3. Infrared imagery taken at 8 a.m., 17 June 1983

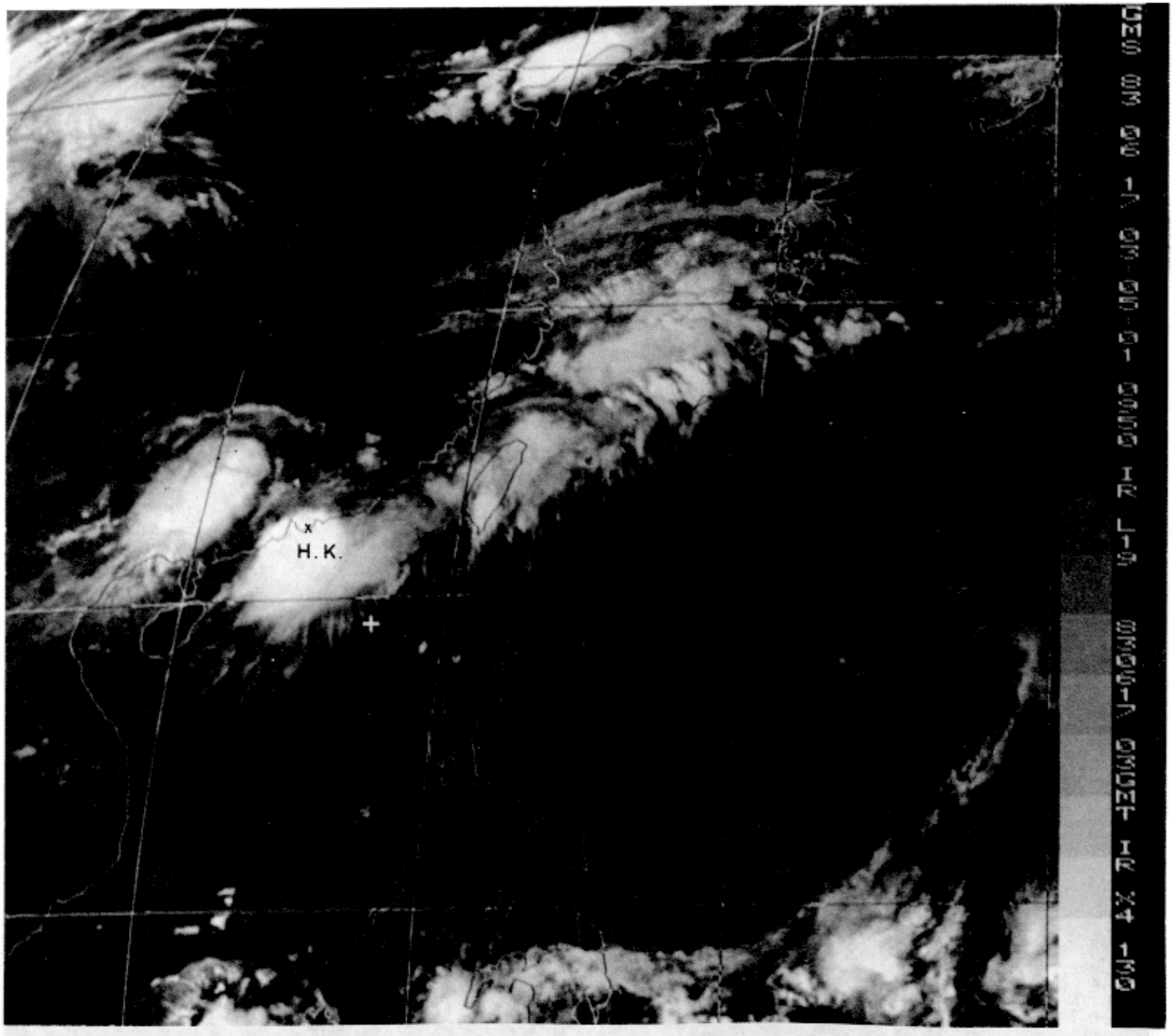


Plate 4. Infrared imagery taken at 11 a.m., 17 June 1983

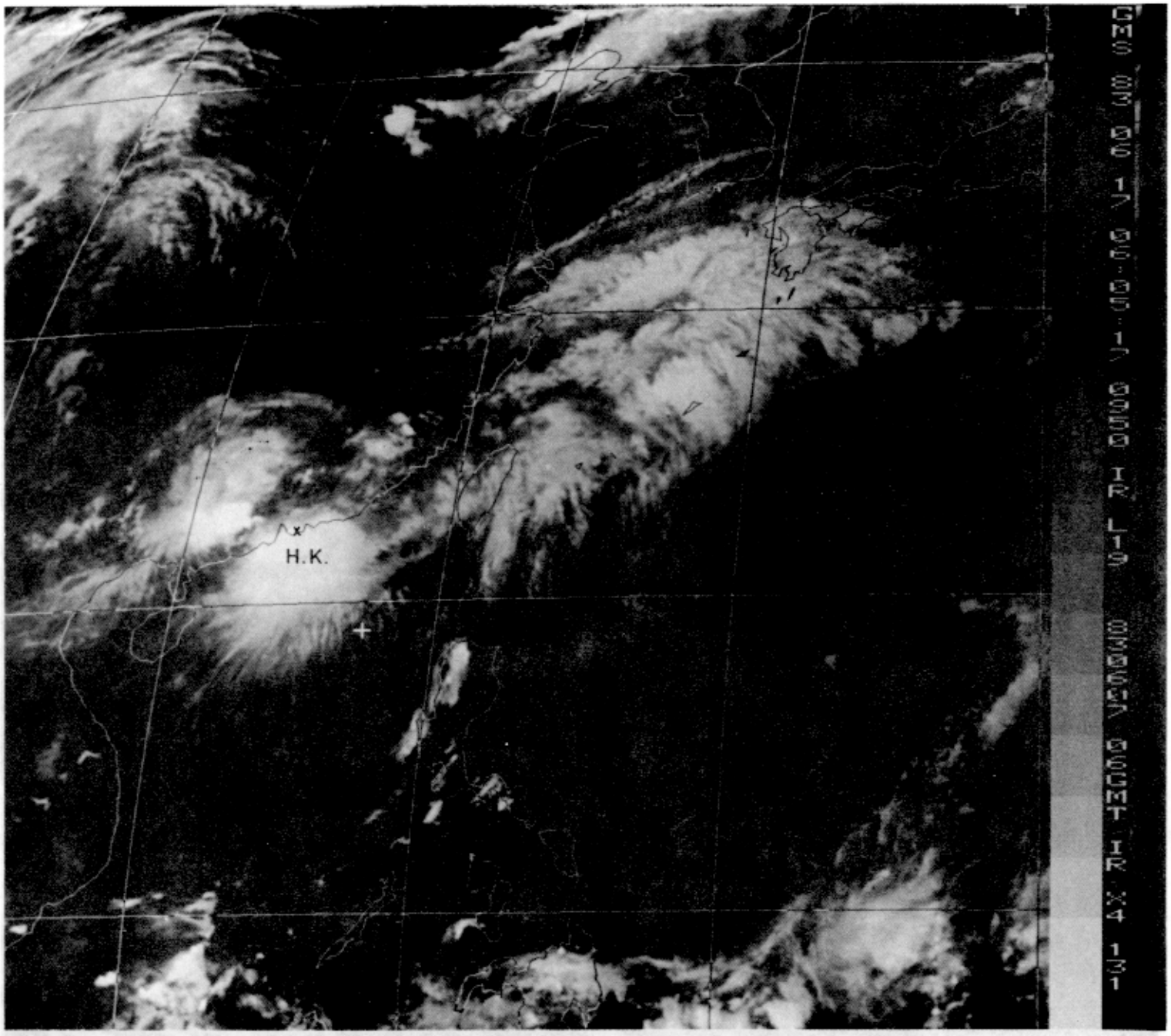


Plate 5. Infrared imagery taken at 2 p.m., 17 June 1983

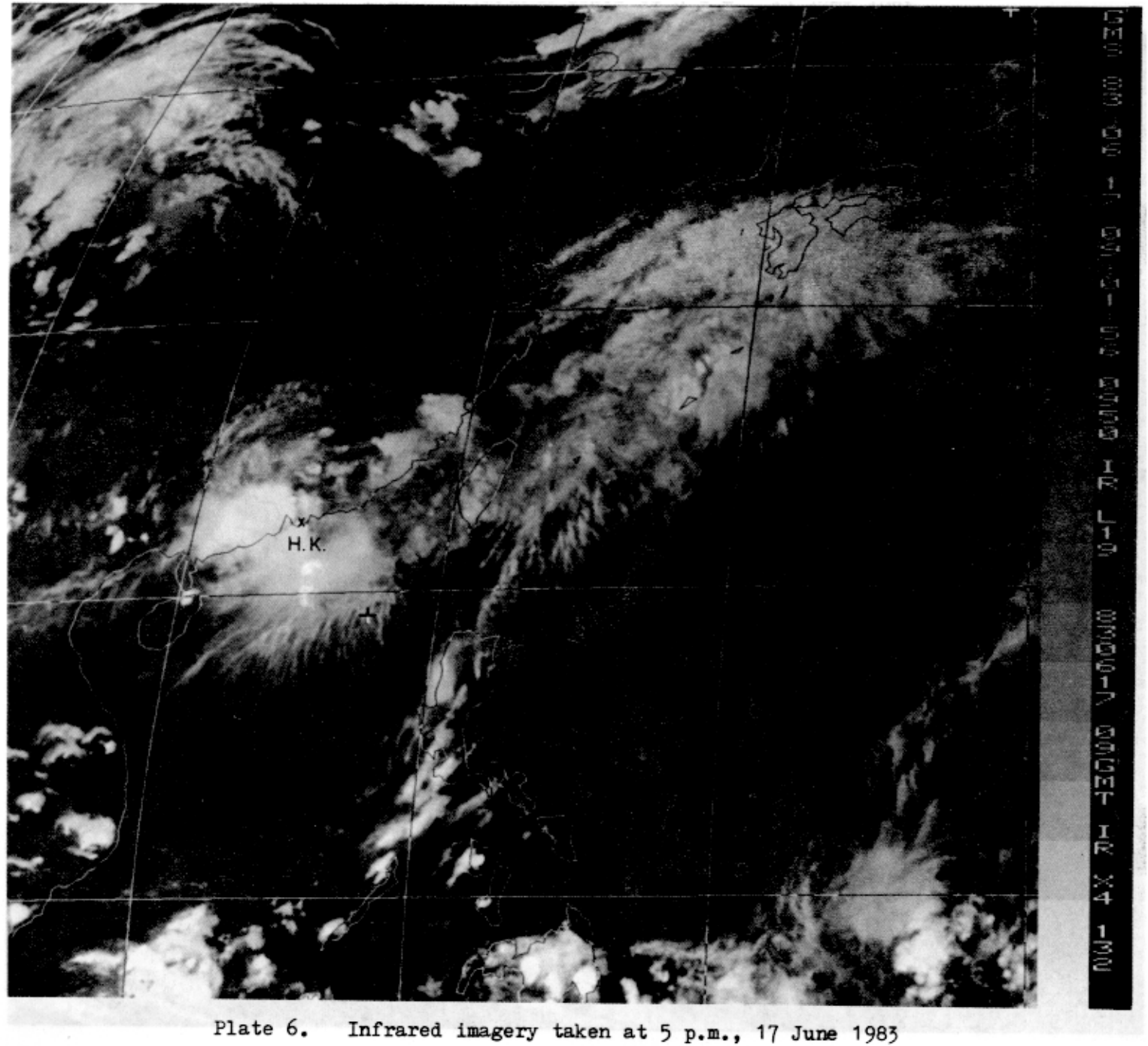


Plate 6. Infrared imagery taken at 5 p.m., 17 June 1983

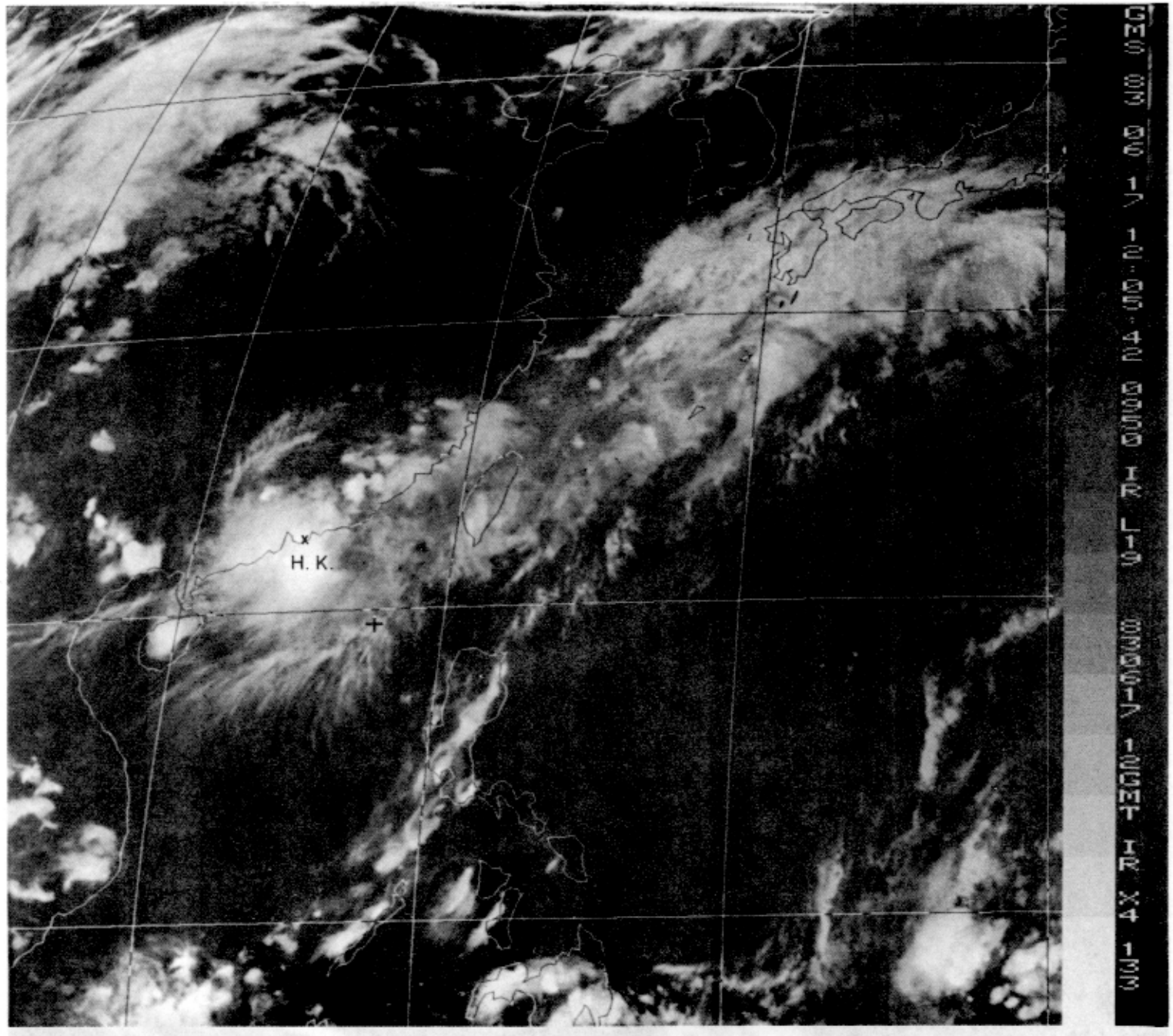


Plate 7. Infrared imagery taken at 8 p.m., 17 June 1983

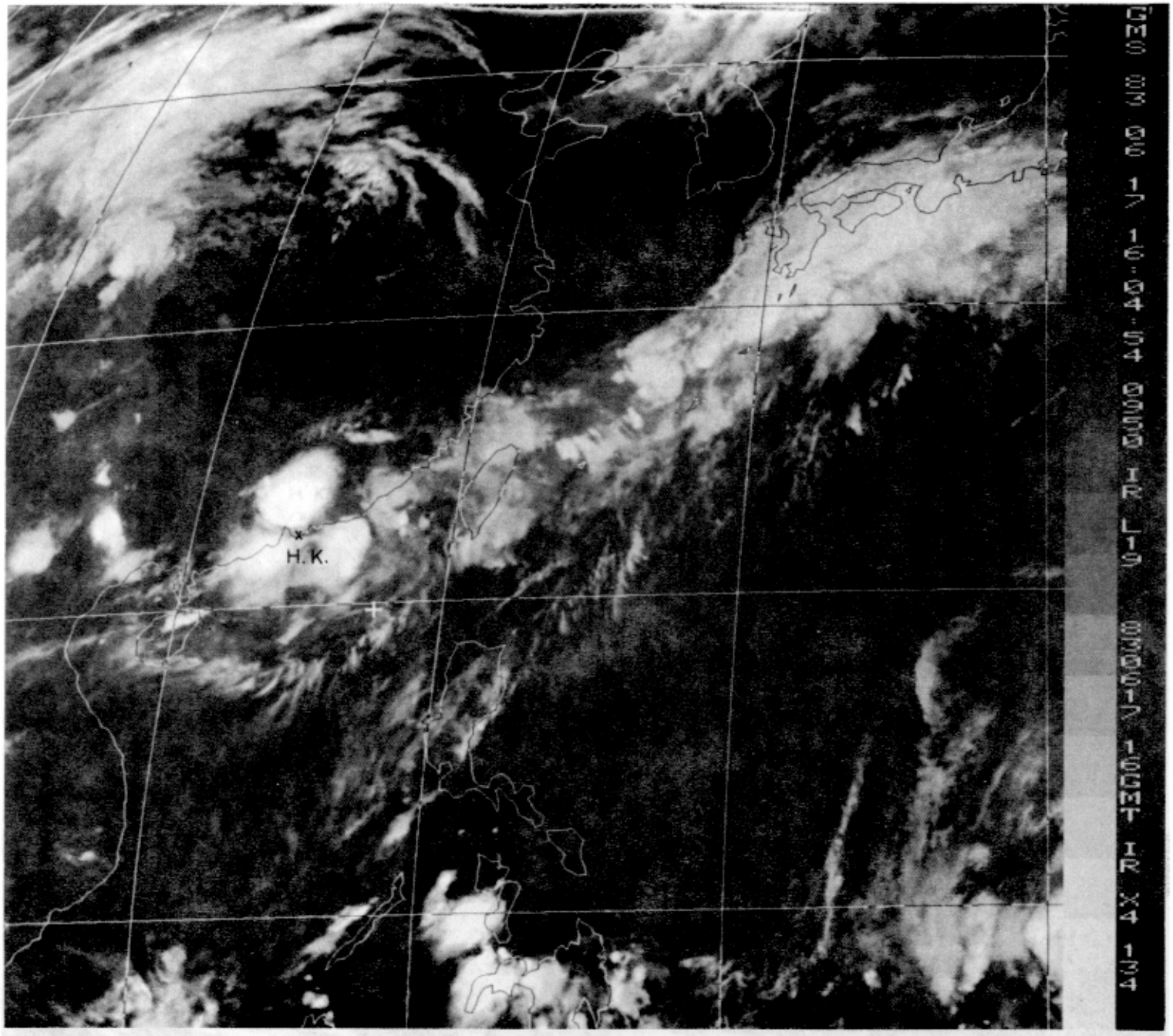


Plate 8. Infrared imagery taken at midnight, 17 June 1983